Energy & Sustainability

Conventional, Renewable and Transitional

SENS 714
Fall 2023

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Director of Engineering, Dolphine Energy

Dr. Khalid M. Al-Khori

❑ *Education:*

- ✓ BSc. degree of **Science in Electrical Engineering** from University of Miami; Florida 1997
- ✓ **EMBA in Energy** from HEC Paris; Doha 2014
- ✓ Ph.D. in **Sustainable Energy Ph.D.** from HBKU; Doha 2020.

❑ *Career:*

- ✓ Total experience of 26 years in Oil & Gas sector.
- ✓ Started career as Process Control Engineer in QP-Refinery
- ✓ Join Dolphin Energy in 2010 and currently **Engineering Director**.

❑ *Award:*

- ✓ Recipient of the **Platinum Award for PhD** from HH Sheikh Tamim bin Hamad Al Thani – Amir of the State of Qatar during the Education Excellence Award Day 2022.

Energy

Contents

Fossil fuels into the energy context

Fossil fuels: oil, coal and natural gas

LNG Market

Dolphin Energy Sustainability report

Renewable Energy into the energy context

RE: Solar, Wind, Hydropower, Biomass, Geothermal

Hydrogen and Fuel Cells

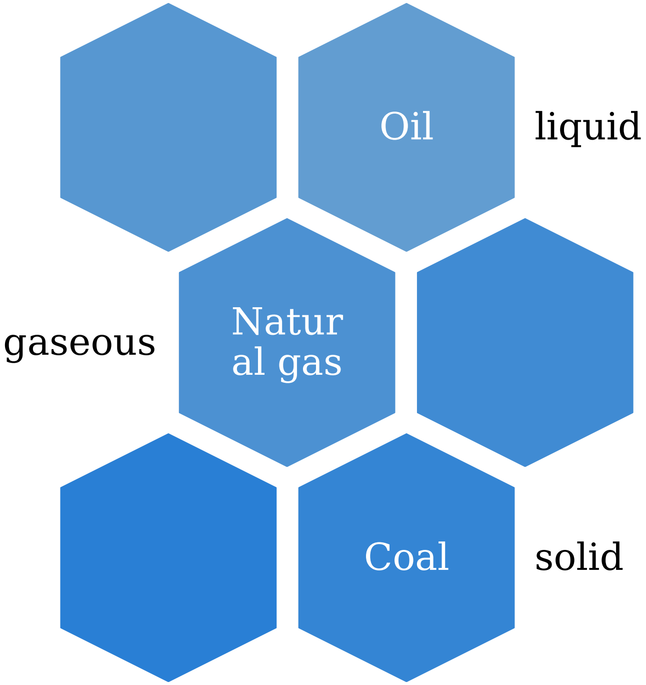
Life Cycle Assessment

Energy Trends:

Fossil Fuels, Past, Present and Future

The fossil fuels

- There are 3 main fossil fuels: oil, coal and natural gas
- They are called fossil because they were **accumulated from the fossil remains of animals and plants in past geological eras**.
- They are called fuels because they **react with O2 and energy sources to produce combustion**.
- Whether we like them or not, they were the energy fuels to sustain our development throughout the Industrial era and they are **still the main currently energy sources.**
- We cannot live without them yet, but we should do it in the future.

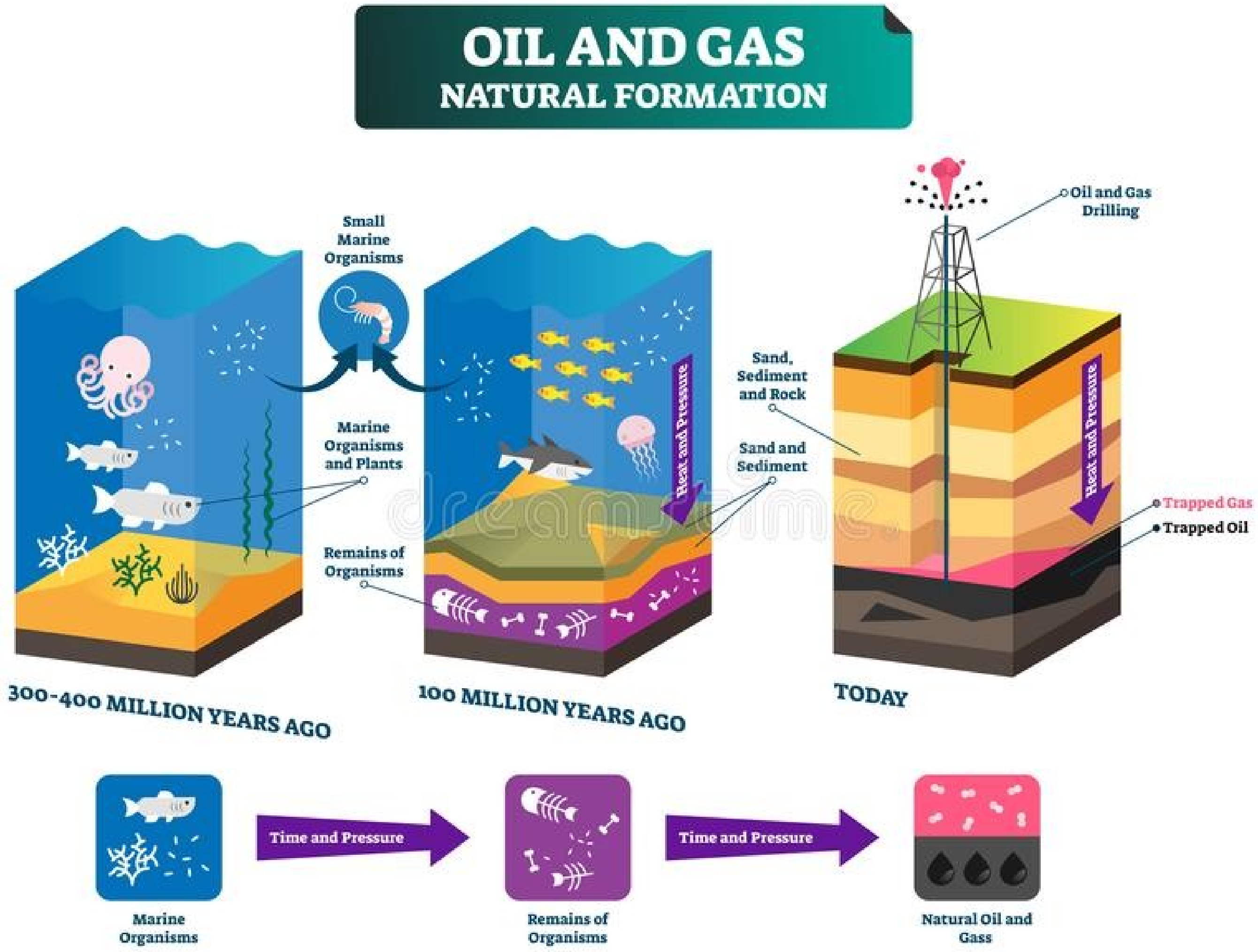


Oil liquid

gaseous Natural gas

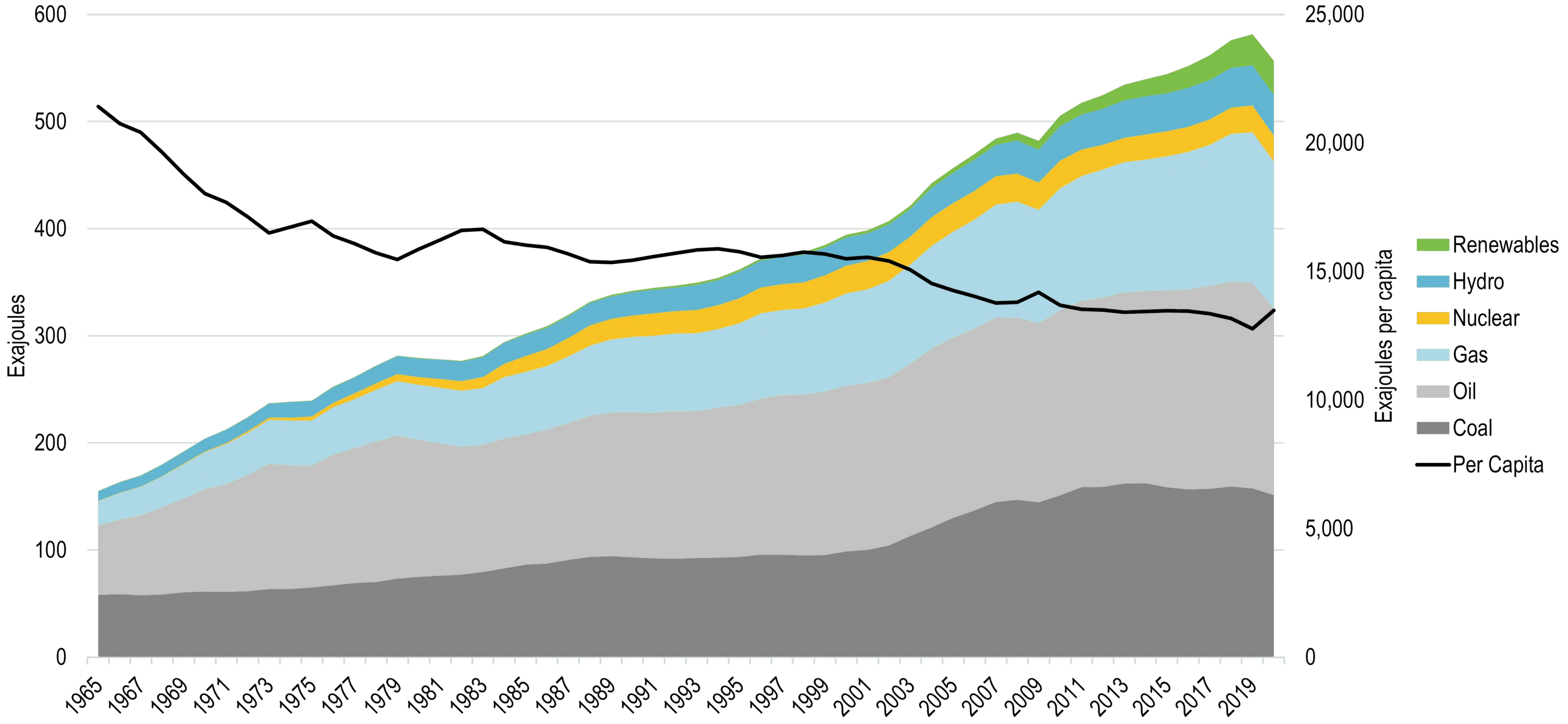
Coal solid

The nature of fossil fuels


OIL AND GAS
NATURAL FORMATION
Small Marine Organisms
Marine Organisms and Plants
Remains of Organisms
Sand, Sediment and Rock
Sand and Sediment
Heat and Pressure
Heat and Pressure
Oil and Gas Drilling
Trapped Gas
Trapped Oil
300-400 MILLION YEARS AGO
100 MILLION YEARS AGO
TODAY
Marine Organisms
Time and Pressure
Remains of Organisms
Time and Pressure
Natural Oil and Gass

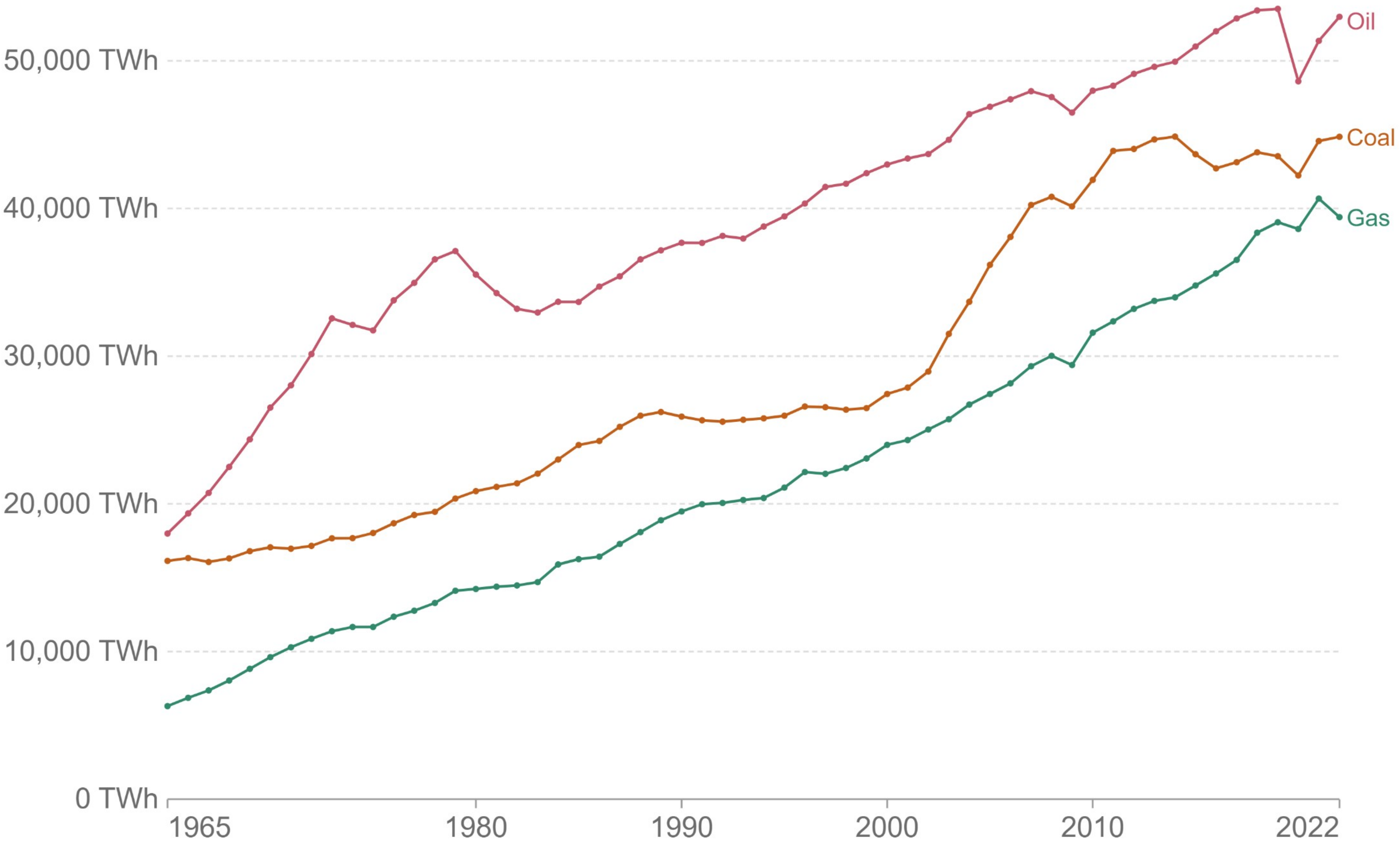
- The first thing we should know about them is that **they are finite resources**, exhaustible at some point in the future.
- The second is that they are **highly pollutant**.
- Their origin and nature is simple: **they are carbon energy resources accumulated of biological remains of distant past eras**. They were **buried for million of years**, representing large reservoirs of energy, but also, stocks of sequestered carbon.
- When we produce and consume them, we are consuming energy from past eras.
- And we are also releasing large reservoirs of carbon accumulations of distant past eras.
- They are UNSUSTAINABLE

Fossil fuels into the energy context



Fossil fuel consumption, World

Fossil fuel consumption is measured in terawatt-hours (TWh).



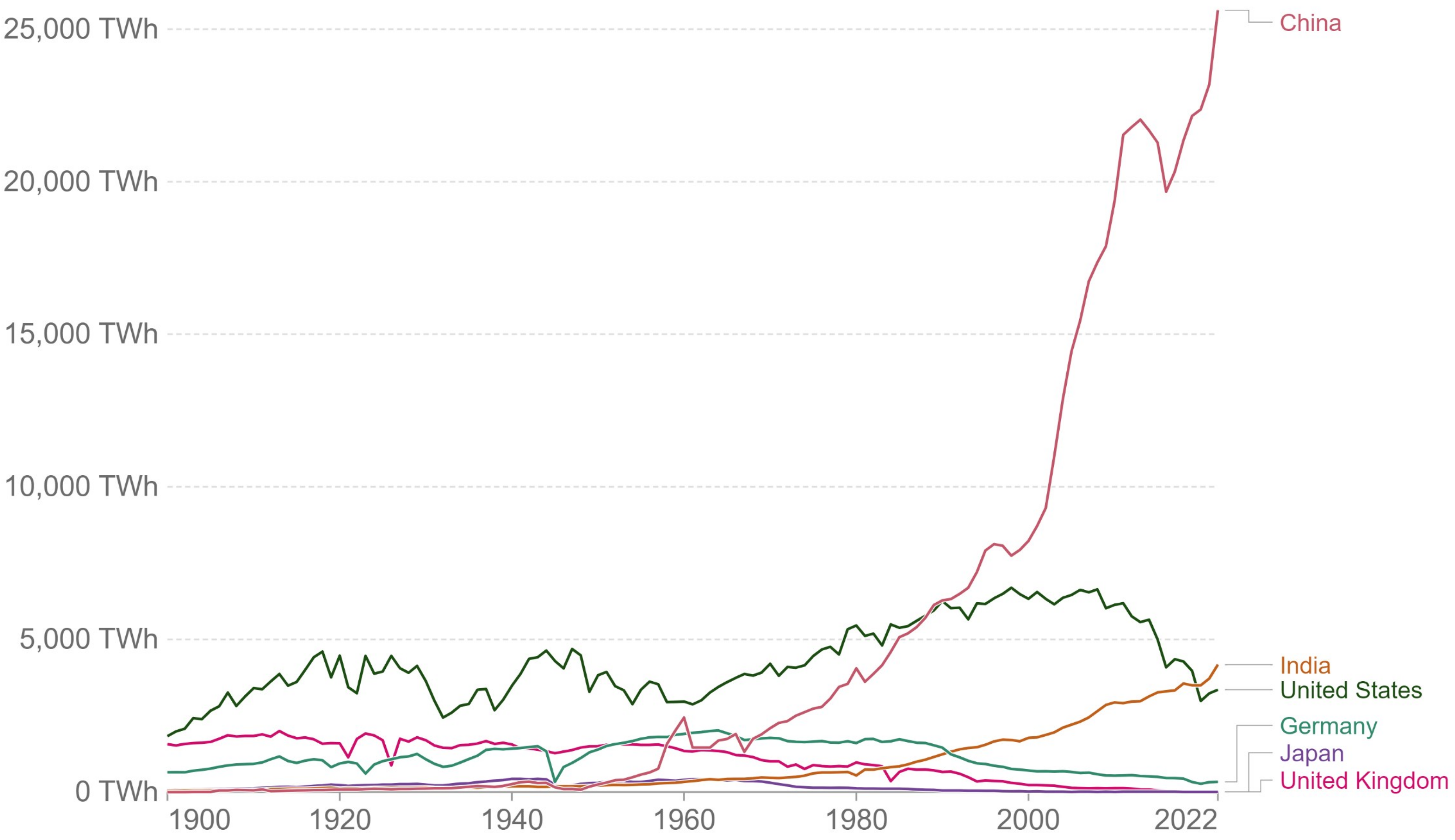
Source: Energy Institute Statistical Review of World Energy (2023)

OurWorldInData.org/fossil-fuels • CC BY

Coal

- Composition (variable): C-H-O-N-S
- **Solid state, black appearance**.
- Types: anthracite, lignite, bituminous.
- Uses: industrial, electricity, heating.
- **Originated from fossilized terrestrial plant material**
- History as FF: in the past the most widely used, remains highly important and strongly linked to the increase of FF worldwide (China, India, etc.)
- **The most pollutant of all FF and with a high contribution to releases of CO2**.
- Its future is highly constrained due to environmental commitments.
- Used on the Medieval China around the 12th century
- **Widely used as fuel for ships and trains as well as industrial activities during the XIX century**.
- **However, it is still largely used as the 2nd source of global primary energy**, in developing nations for power, industrial activities, etc.

Coal production



Source: Energy Institute Statistical Review of World Energy (2023); The Shift Data Portal
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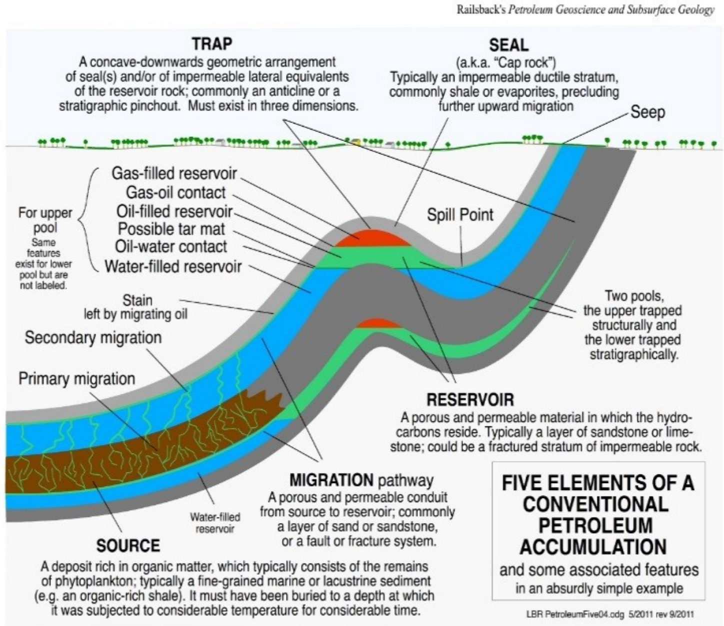
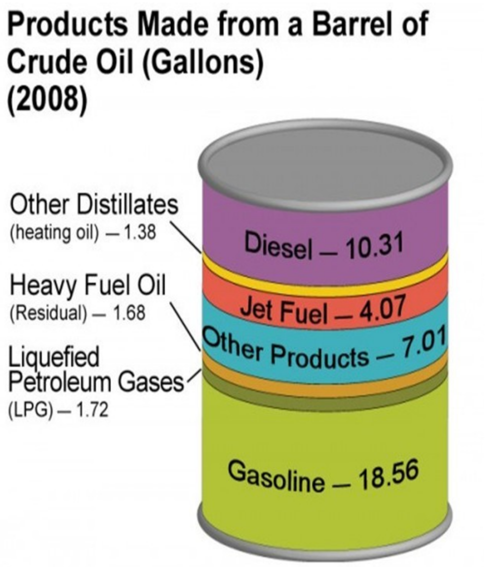
Oil

- Yellow to black liquid fuel found in geological formations.
- **1859: First oil well drilled PA, US by Captain Drake**
- **1920s-1930s: Giant oil fields are discovered in Middle East, turning it a critical geopolitical region**
- 1945-1973: Oil demand grows incredibly after development of American industry and chemistry
- 1973 & 1979: Supply oil shocks made the world aware of vulnerabilities of depending on oil.
- 1991: Iraq War, control of oil fields
- 1998-1999: bottom oil prices, depressed industry
- 2005-2020: new oil supplies come online from unconventional fields in the US.
- **2008 Peak oil price and economic downturn**
- After 2014: relative low prices in the world


Railsback's Petroleum Geoscience and Subsurface Geology
TRAP
A concave-downwards geometric arrangement of seal(s) and/or of impermeable lateral equivalents of the reservoir rock; commonly an anticline or a stratigraphic pinchout. Must exist in three dimensions.
SEAL
(a.k.a. "Cap rock")
Typically an impermeable ductile stratum, commonly shale or evaporites, precluding further upward migration
Seep
For upper pool
Same features exist for lower pool but are not labeled.
Gas-filled reservoir
Gas-oil contact
Oil-filled reservoir
Possible tar mat
Oil-water contact
Water-filled reservoir
Spill Point
Stain left by migrating oil
Secondary migration
Primary migration
Two pools, the upper trapped structurally and the lower trapped stratigraphically.
RESERVOIR
A porous and permeable material in which the hydrocarbons reside. Typically a layer of sandstone or limestone; could be a fractured stratum of impermeable rock.
MIGRATION pathway
A porous and permeable conduit from source to reservoir; commonly a layer of sand or sandstone, or a fault or fracture system.
Water-filled reservoir
SOURCE
A deposit rich in organic matter, which typically consists of the remains of phytoplankton; typically a fine-grained marine or lacustrine sediment (e.g. an organic-rich shale). It must have been buried to a depth at which it was subjected to considerable temperature for considerable time.
FIVE ELEMENTS OF A CONVENTIONAL PETROLEUM ACCUMULATION
and some associated features in an absurdly simple example
LBR PetroleumFive04.odg 5/2011 rev 9/2011



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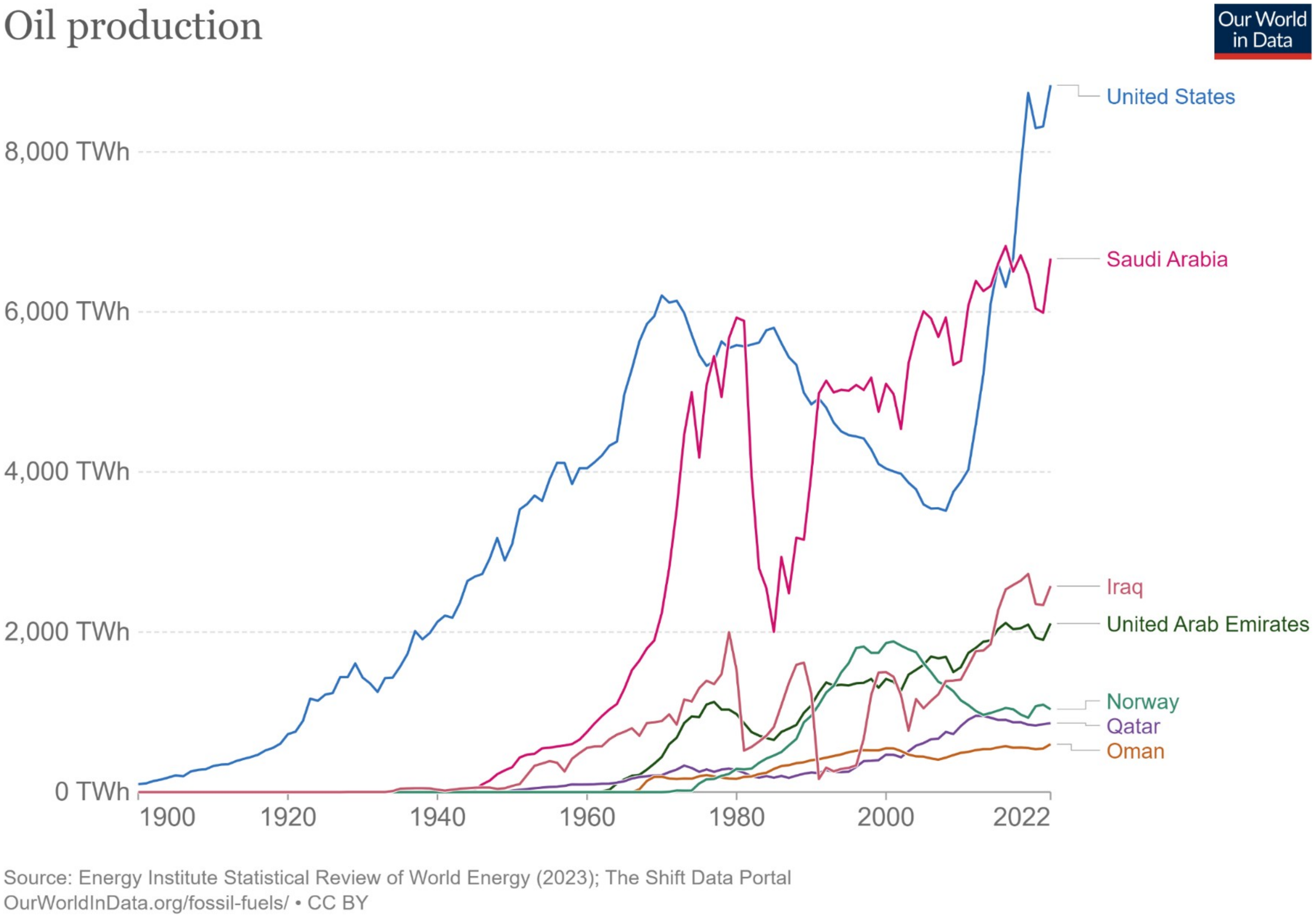
Feb. 21 - 1922
G.H. FARNUM
OKEMAH, OKLA.

- **Middle East is still the dominant production/supplier region.**
- The last 10 years have accounted a dramatic increase on the North American (US) production out of the US shale boom
- Ex URSS countries (CIS) are also increasing their output.
- In general, we are still increasing our absolute quantities of oil production.
- If the trend continues, Middle East would lose importance as the largest producing region.



Source: Energy Institute Statistical Review of World Energy (2023); The Shift Data Portal
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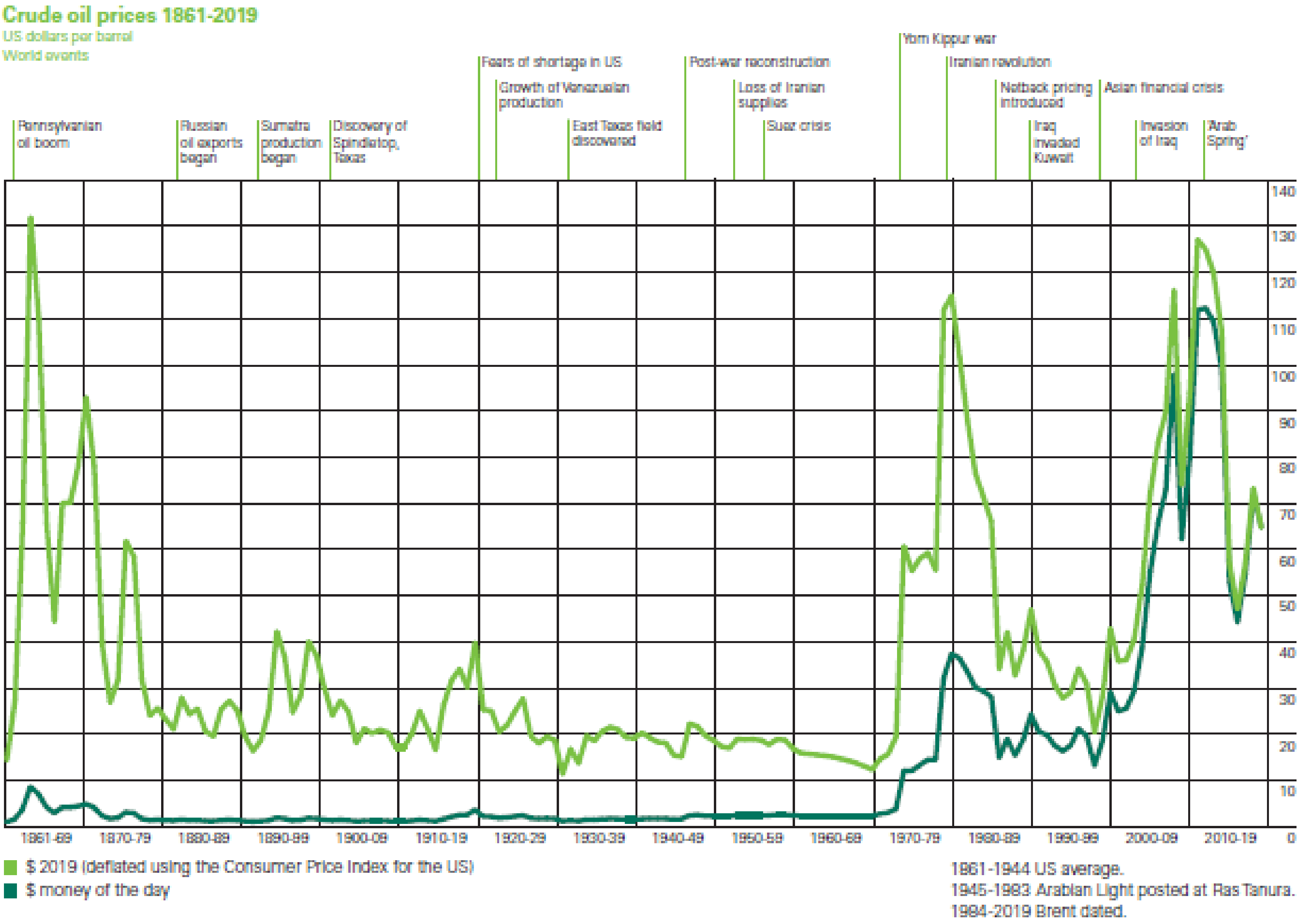
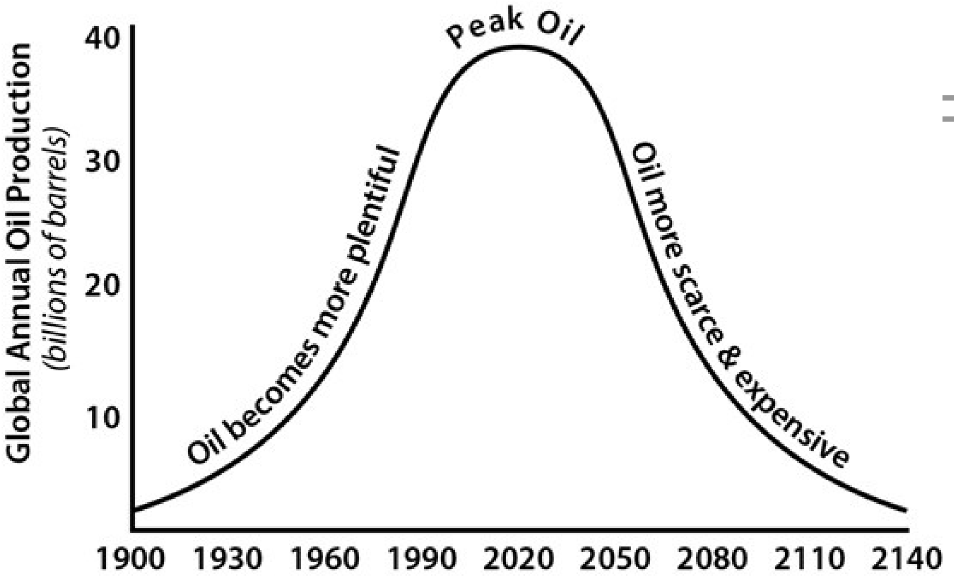
Crude oil prices through history

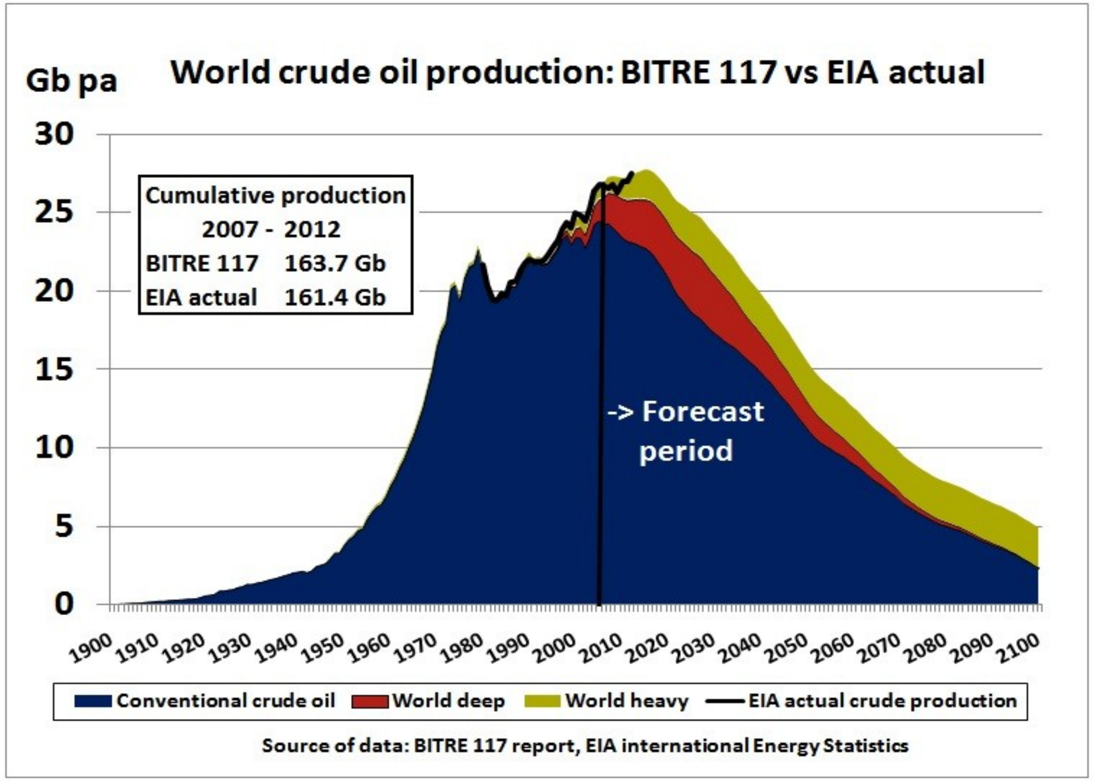


- **Crude oil prices always linked to major global events in the last 150 years.**
- In times of political crisis, disputes, wars, oil prices skyrocket very high.
- **In turn, when there are economic downturns or large production periods, oil prices depress.**
- In general, when oil resources start to dwindle, prices will soar

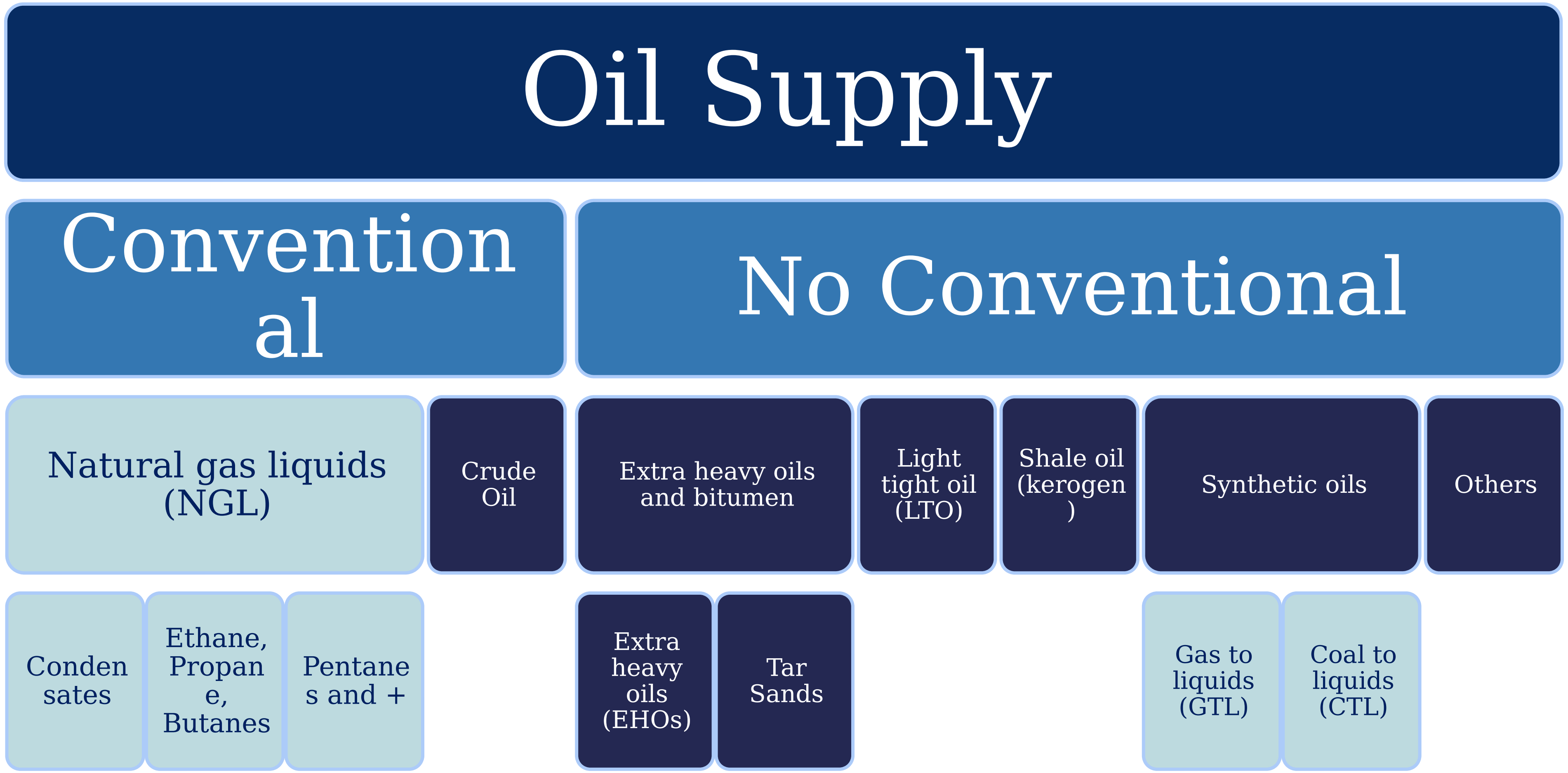
Peak oil

- As a non-renewable resource, there is a limited resource quantity of oil.
- **We are not sure with certainty of how much in total it is out there, but we are sure it is limited.**
- Thus, sometime in the future, oil production will peak and then decline.
- That is known as peak oil, a model proposed M. King Hubbert. It applies likewise to any mineral resource with finite quantities.
- **It is forecasted that the world oil production would peak somewhere between 2005 and 2025. However, new technological developments and new resources may change such date.**
- **Once reached the peak, production would decline, supply too and prices start to rise.**
- So, even before oil becomes depleted, prices and stocks would turn it non-commercial





Source of data: BITRE 117 report, EIA international Energy Statistics



Oil Supply

- Conventional
  - Natural gas liquids (NGL)
    - Condensates
    - Ethane, Propane, Butanes
    - Pentanes and +
  - Crude Oil
- No Conventional
  - Extra heavy oils and bitumen
    - Extra heavy oils (EHOs)
    - Tar Sands
  - Light tight oil (LTO)
  - Shale oil (kerogen)
  - Synthetic oils
    - Gas to liquids (GTL)
    - Coal to liquids (CTL)
  - Others

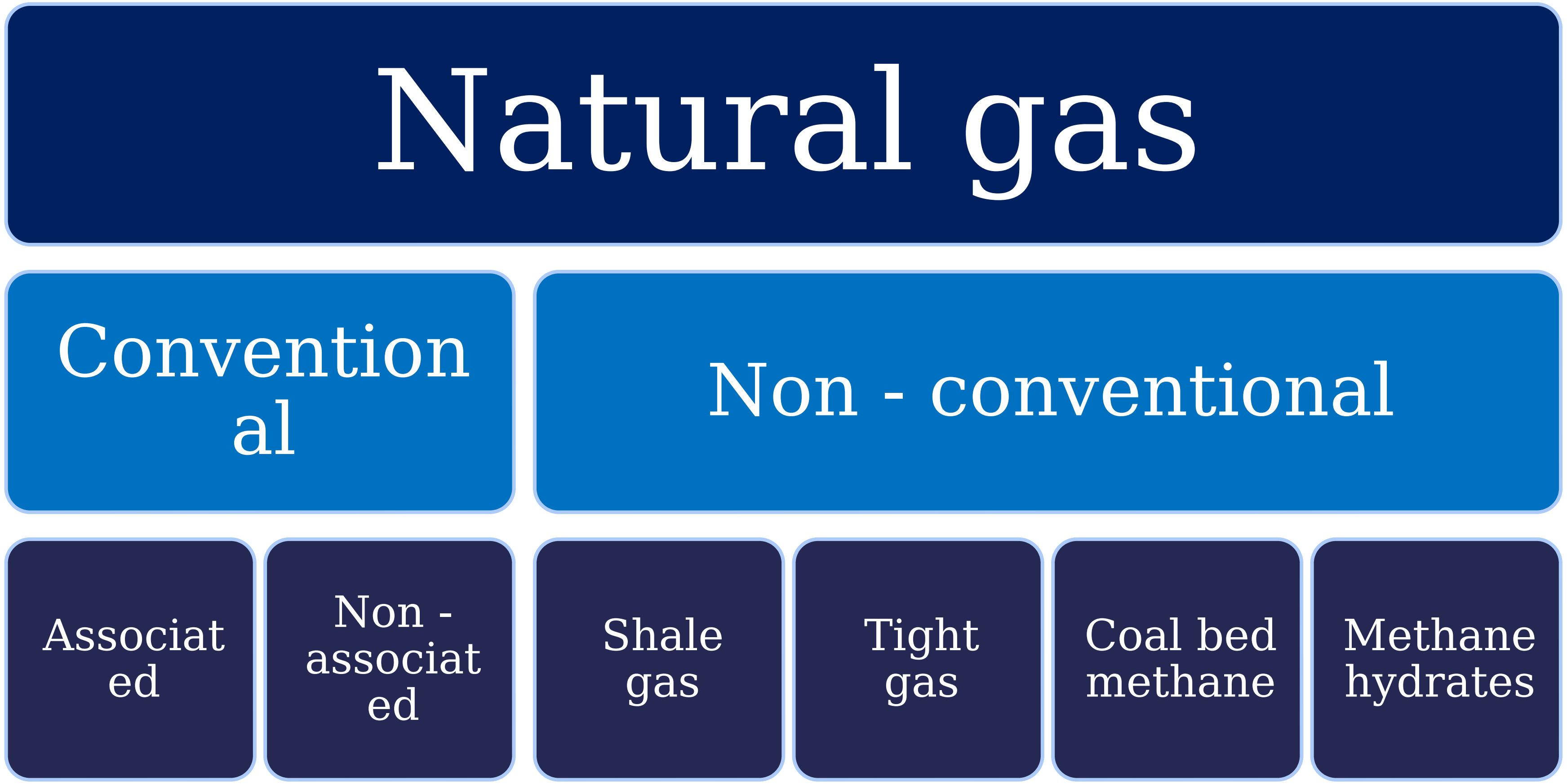
Natural gas

- **The cleanest of all fossil resources**
- **25% of global energy consumption**
- **The energy resource with the highest growth.**
- **Mostly formed of methane (CH4)** in great percentage, ethane, propane and traces of larger hydrocarbons
- **Possible replacement of oil / coal and transition resource towards cleaner energies.**
- However, the difference comes from the depth: Biological deposits at deeper layers are subject to higher pressures and temperatures, breaking them down and turning them into simpler hydrocarbons
- Initially used for Town gas and gas lamps.
- **Associated with the oil production, it was initially treated as a by-product and vented or flared.**
- **First long-distance pipeline in 1925 – USA**
- 1930’s: development of high resistance steel for pipes
- After the 50’s: major NG discoveries.
- **1969: first LNG cargo from Algeria**
- 1980s: LNG market starts growing
- **1996-97: Qatar first LNG shipment**

FIRST INDIANA NATURAL GAS WELL

One mile southwest of this marker gas was discovered in 1867 by G. Bates while drilling for oil at a depth of 500 feet. Gas wells were drilled in 1887-1888; gas piped into Francesville lasted only four years.

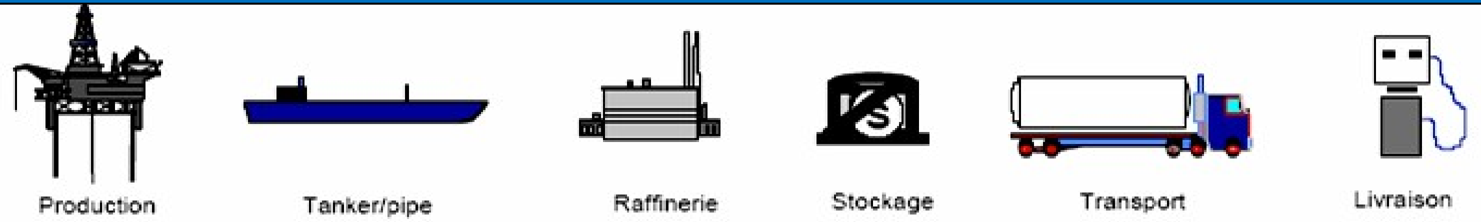
Natural gas sources



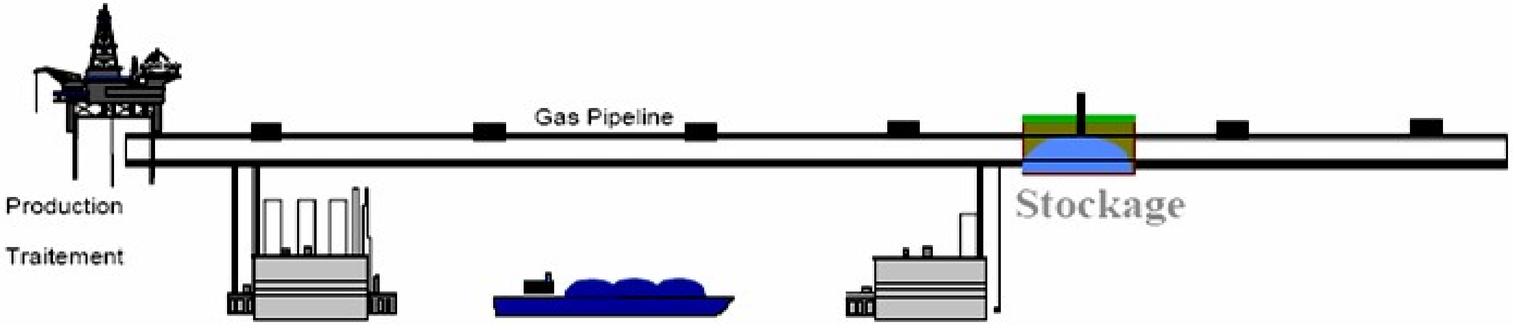
- Natural gas
  - Conventional
    - Associated
    - Non - associated
  - Non - conventional
    - Shale gas
    - Tight gas
    - Coal bed methane
    - Methane hydrates

Oil & Gas: two radically different commodities

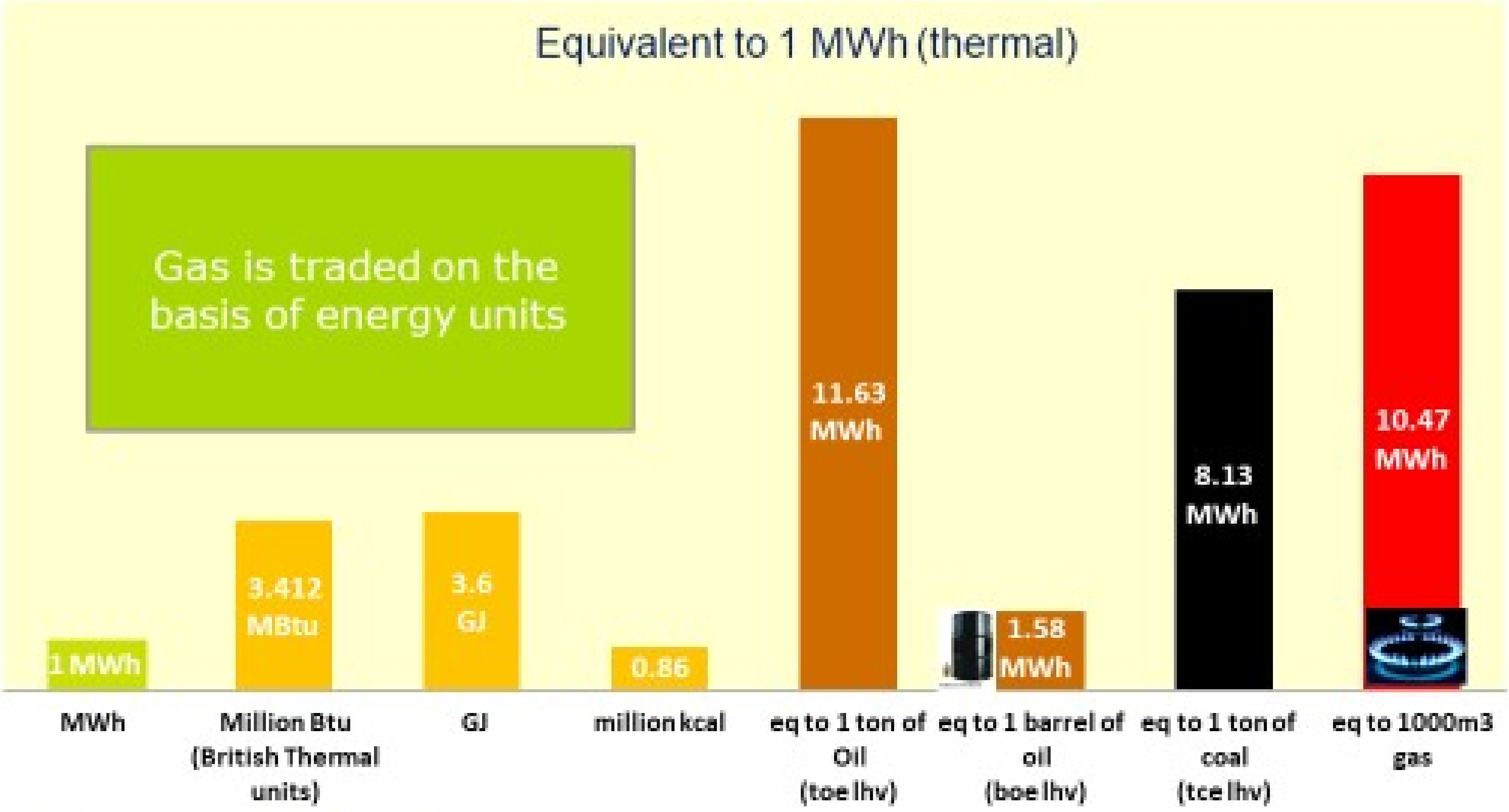
Oil is liquid: easy and cheap to ship, store and move


Production
Tanker/pipe
Raffinerie
Stockage
Transport
Livraison

Gas (CH4) is gaseous!...complex and costly to ship & store


Gas Pipeline
Stockage
Production
Traitement

Gas Units

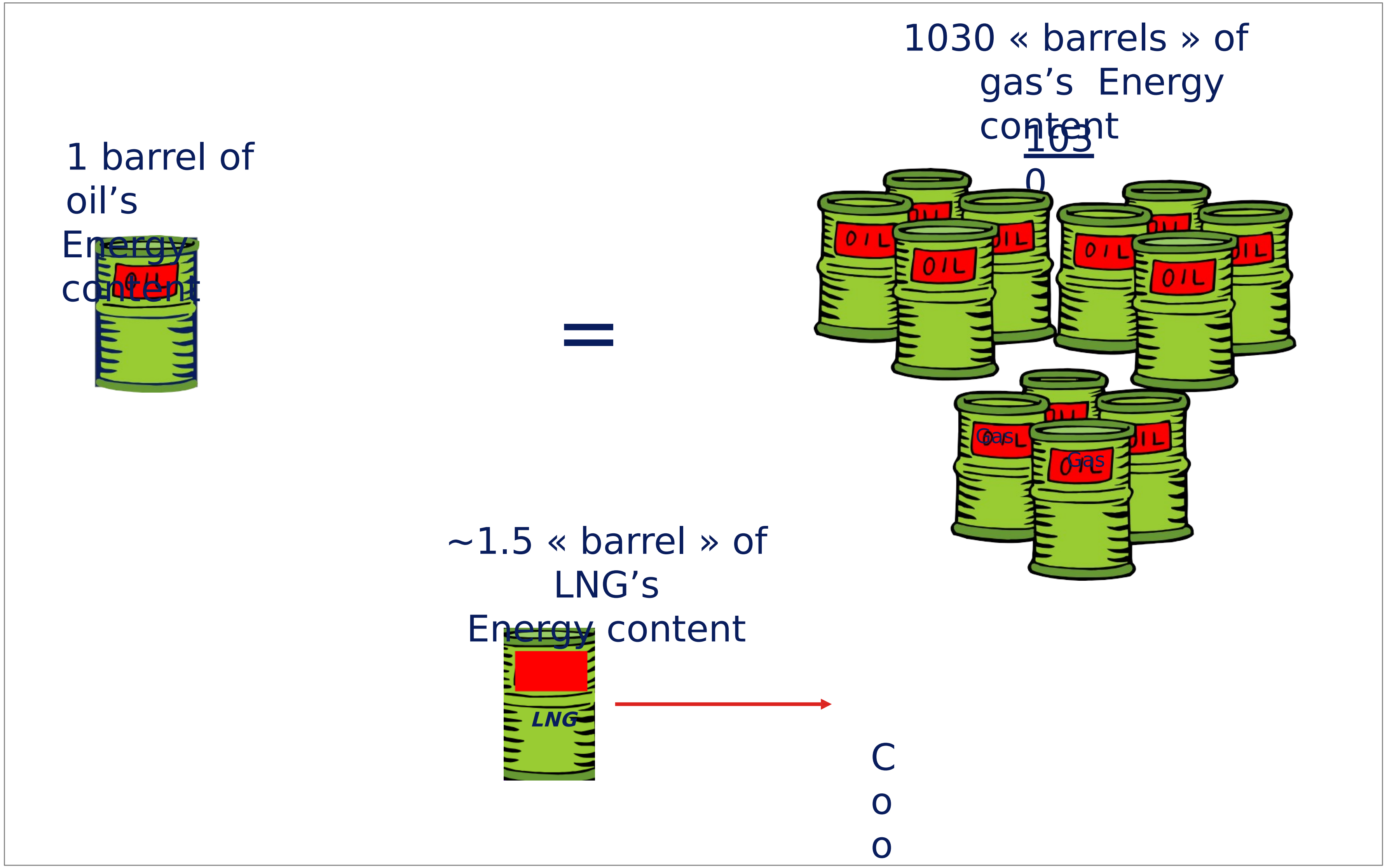


Equivalent to 1 MWh (thermal)

Gas is traded on the basis of energy units

➔ 1MWh equivalent to 34.12 Therm

The problem with gas is its bulkiness



1 barrel of oil's Energy content

=

1030 « barrels » of gas's Energy content

1030

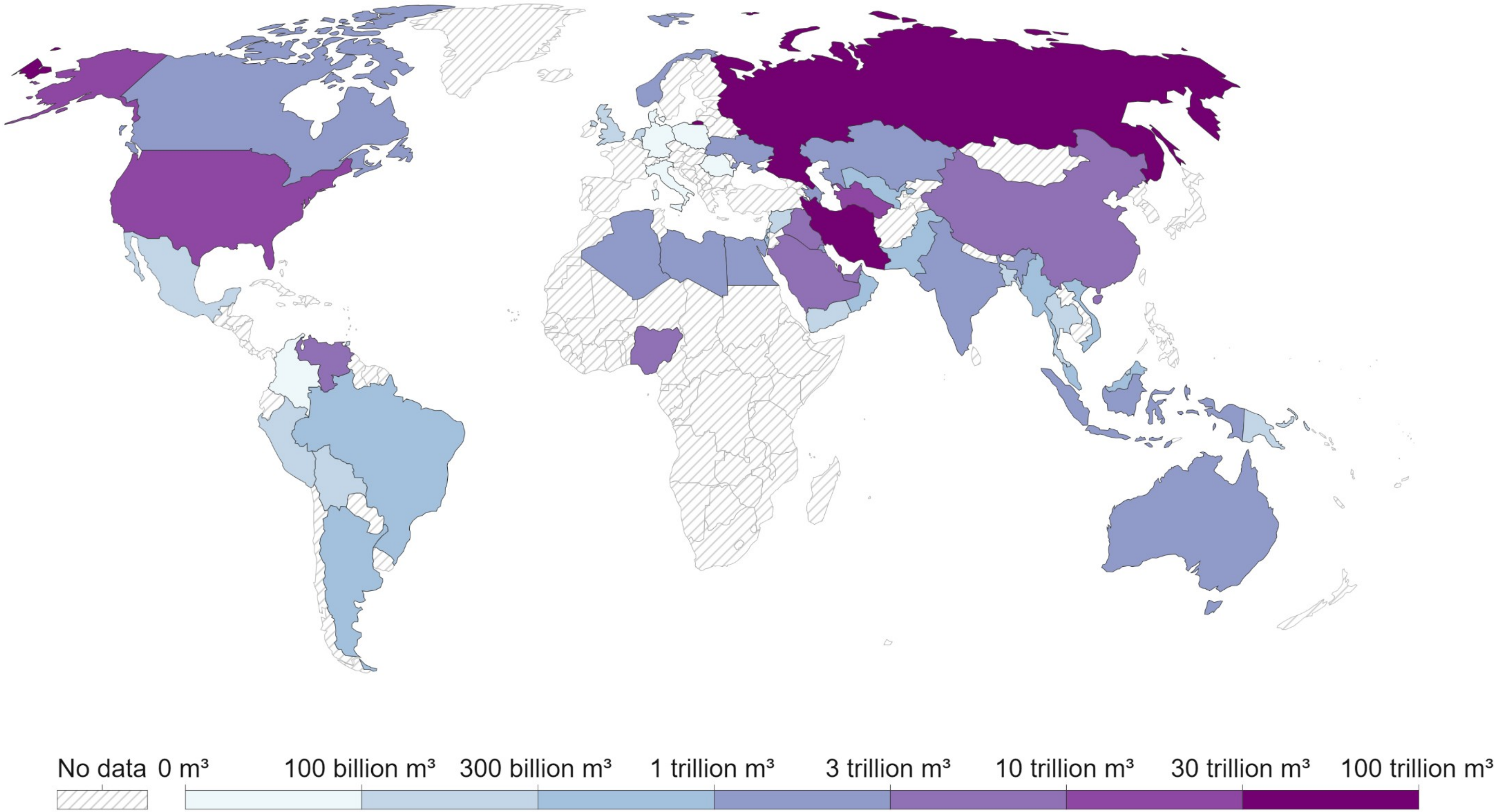
~1.5 « barrel » of LNG's Energy content

Cool

Gas reserves, 2020

Our World in Data

Proved reserves, measured in cubic meters, are generally those quantities that can be recovered in the future from known reservoirs under existing economic and operating conditions, according to geological and engineering information.


No data
▨
0 m³
100 billion m³
300 billion m³
1 trillion m³
3 trillion m³
10 trillion m³
30 trillion m³
100 trillion m³

Source: Energy Institute Statistical Review of World Energy (2023)

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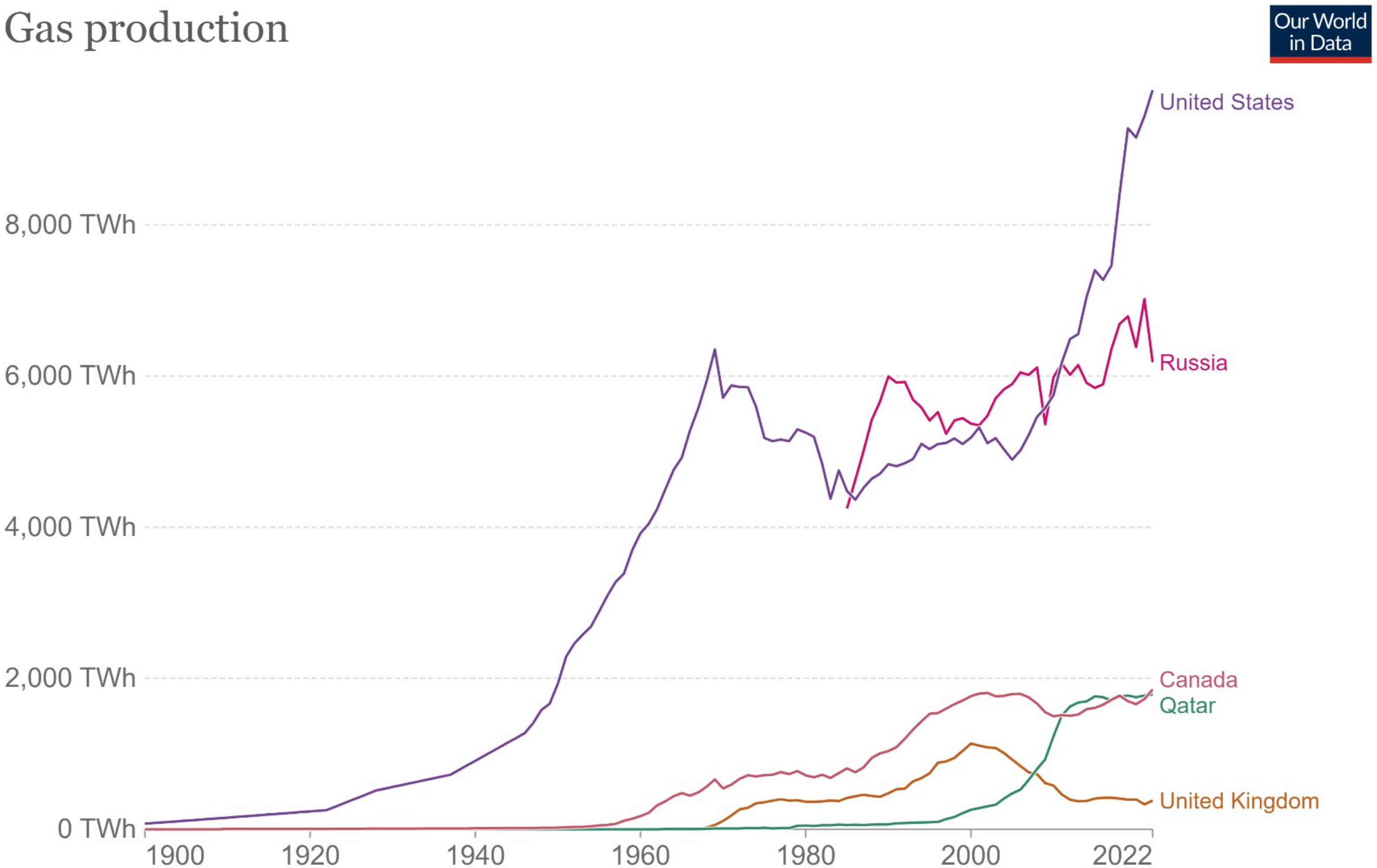
- Global gas production is growing more steeply on the last years
- **North America and the Ex USRR are historically the largest productive regions.**
- The last 15 years have accounted a dramatic increase on the North American production from the US shale gas boom
- **Middle East is growing in gas production steadily from countries like Qatar, Iran, KSA and others.**
- Asia Pacific is also increasing production.
- **Unlike them, Europe is decreasing.**



Source: Energy Institute Statistical Review of World Energy (2023); The Shift Data Portal
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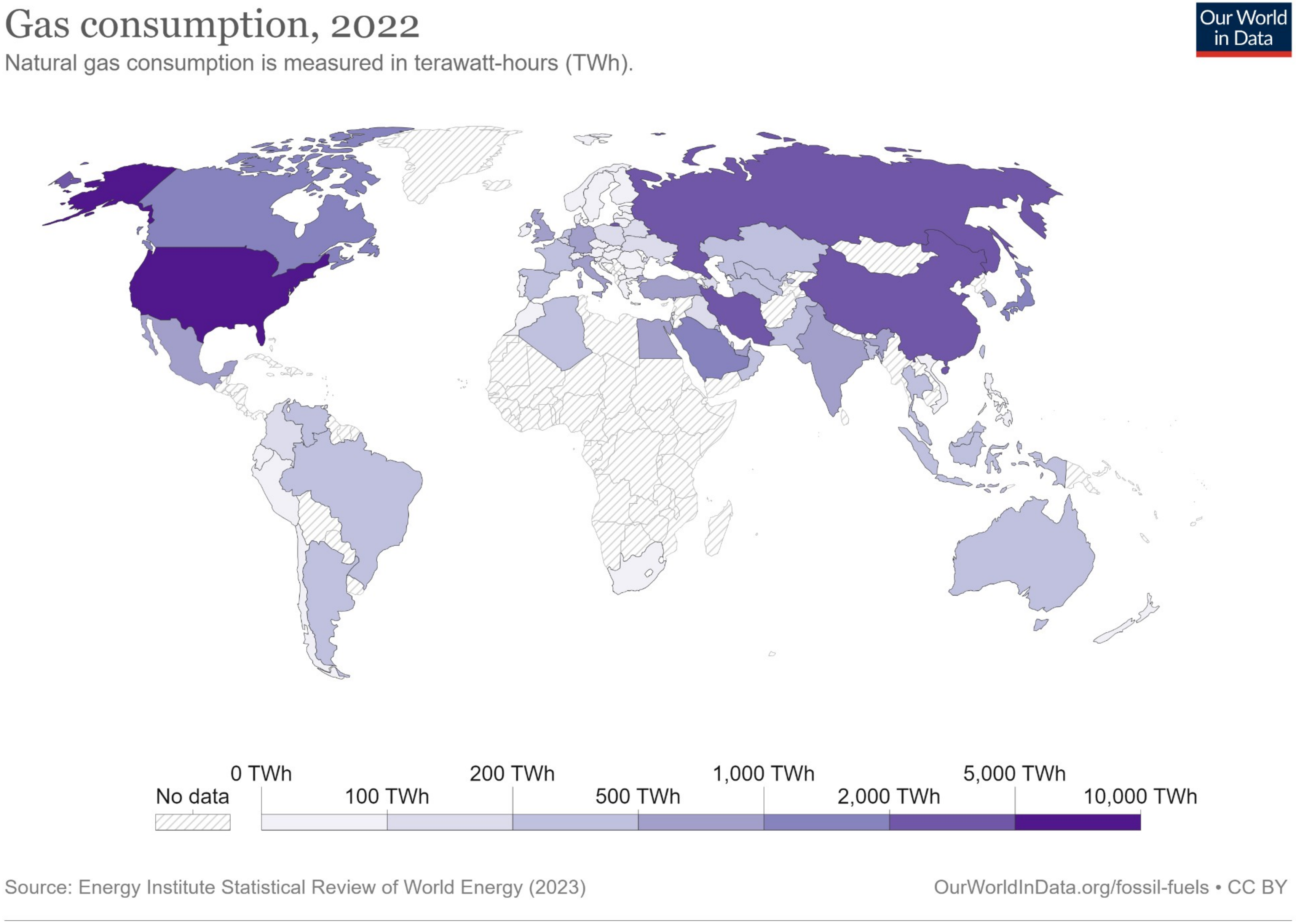
- **North America is not only the largest producer, but consumer as well.**
- Asia Pacific and Middle East are also showing growing trends of consumption.
- **Thus, large producers are also large consumers.**
- Exception: CIS (Ex USRR) which is the largest gas reserve, but with steady consumption and plans to increase exports to other markets.
- **In general, gas consumption is increasing worldwide and we could expect fuel switching from oil and coal in future decades.**



Gas consumption, 2022

Natural gas consumption is measured in terawatt-hours (TWh).

Our World in Data
No data
0 TWh
100 TWh
200 TWh
500 TWh
1,000 TWh
2,000 TWh
5,000 TWh
10,000 TWh

Source: Energy Institute Statistical Review of World Energy (2023)

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World gas conventional proven reserves

- Between 180 to 200 TCM
- Twice the amount produced so far.
- More than 50 years at current rates.
- Increase in discoveries since the 60’s
- However, they are now harder to find
- Geographically uneven distributed

- **Qatar** has the third largest proven reserves of natural gas. Proven reserve of natural gas of **25,000 Bm3** (850 TCF).

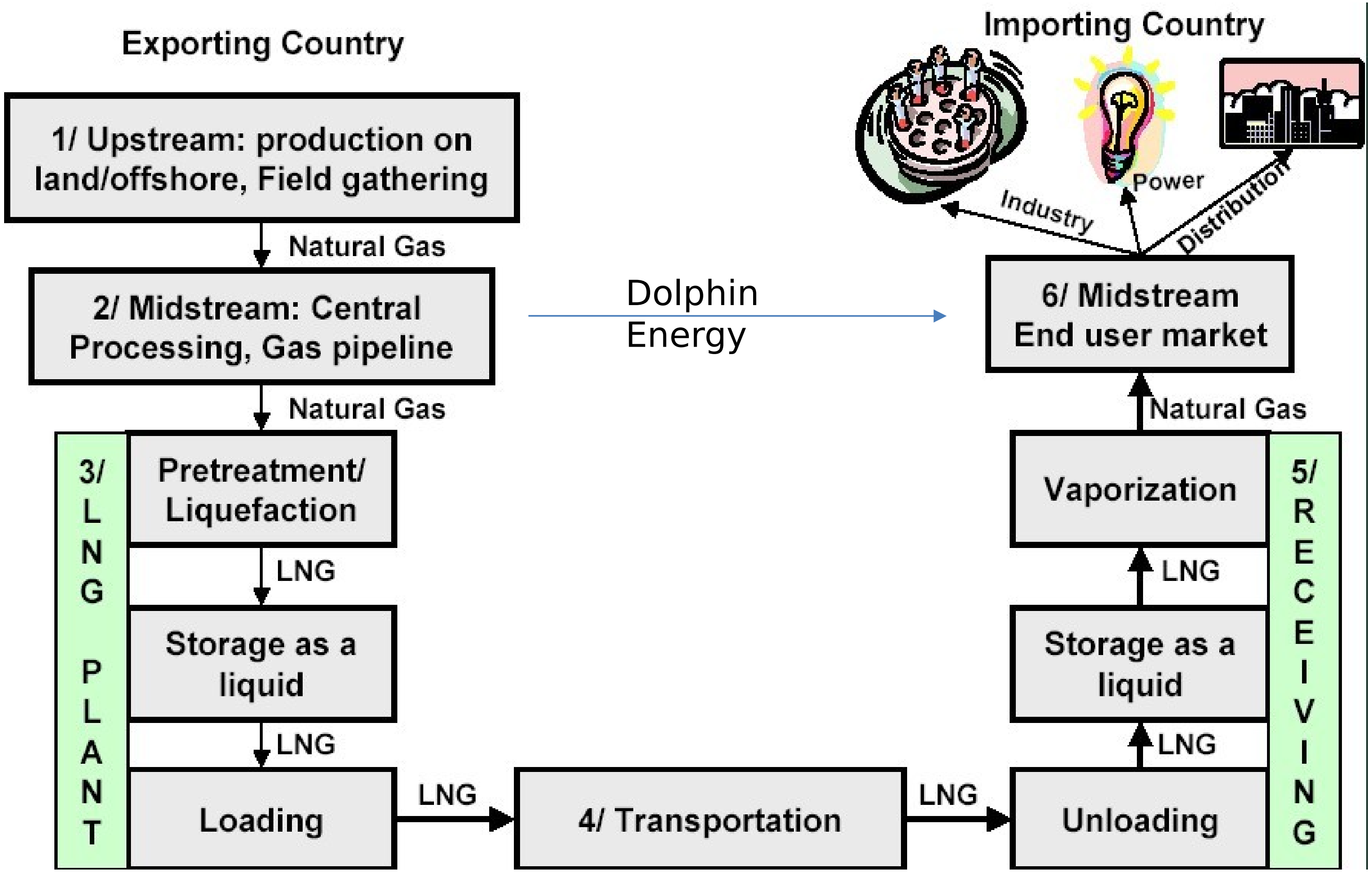
- One of **largest exporter of LNG** in the world:
  - **77 MT** per year **in 2011**
  - **110 MT** per year **by 2026**
  - And **126 MT** per year **by 2027**

Country	Reserves	%
World	192.24	100
Russia	47.77	24.9
Iran	33.59	17.5
Qatar	25.19	13.1
Saudi Arabia	8.15	4.2
USA	7.73	4
Turkmenistan	7.50	3.9
UAE	6.08	3.2
Venezuela	5.52	2.9
Nigeria	5.15	2.7
Algeria	4.50	2.3
China	3.51	1.8
Iraq	3.17	1.6

Quantities in Trillion cubic meters (TCM)

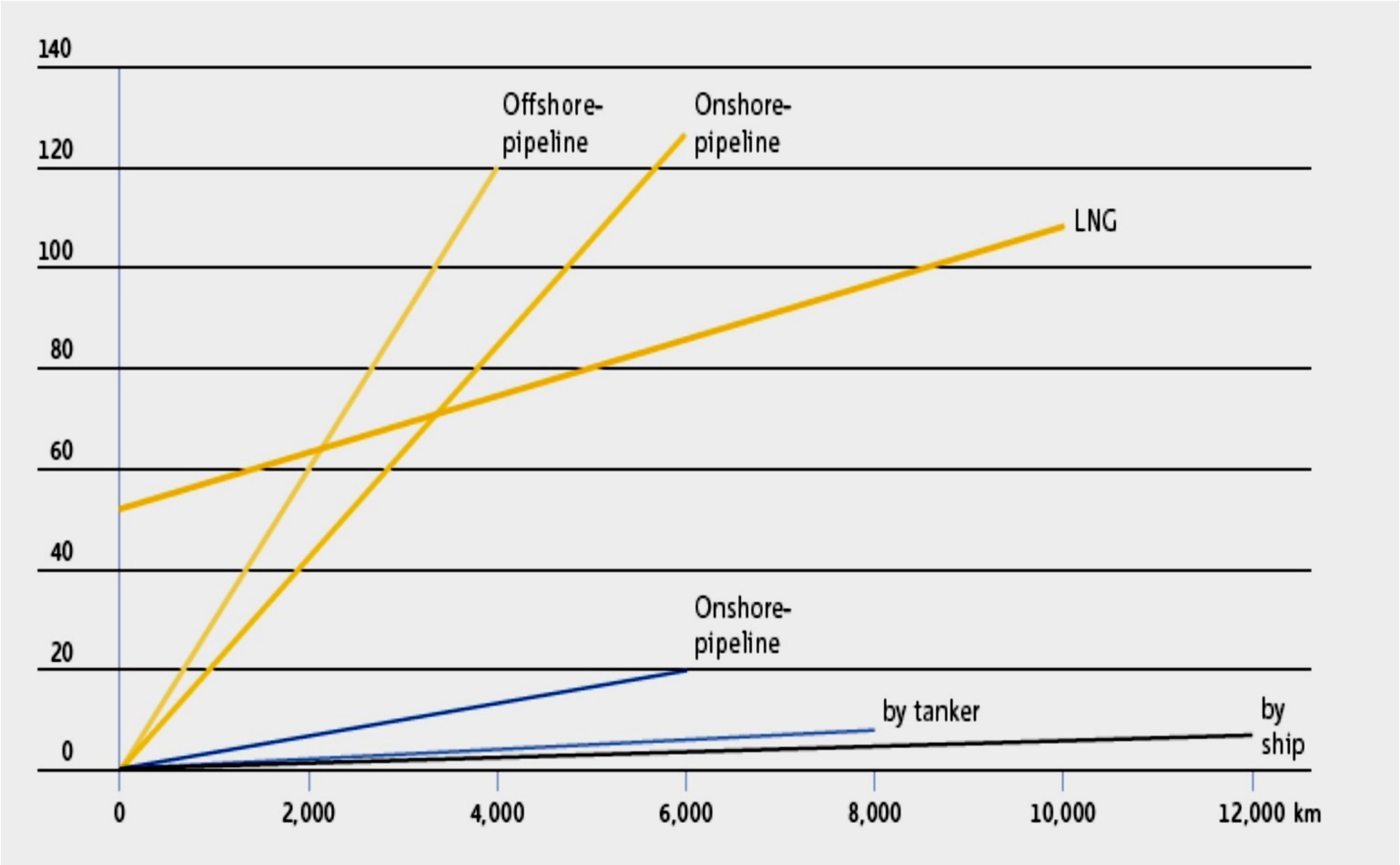
What is Liquified Natural Gas?

The LNG process


Exporting Country
1/ Upstream: production on land/offshore, Field gathering
Natural Gas
2/ Midstream: Central Processing, Gas pipeline
Natural Gas
3/ LNG PLANT
Pretreatment/ Liquefaction
LNG
Storage as a liquid
LNG
Loading
LNG
4/ Transportation
LNG
Unloading
LNG
Storage as a liquid
LNG
Vaporization
5/ RECEIVING
Natural Gas
6/ Midstream End user market
Industry
Power
Distribution
Importing Country

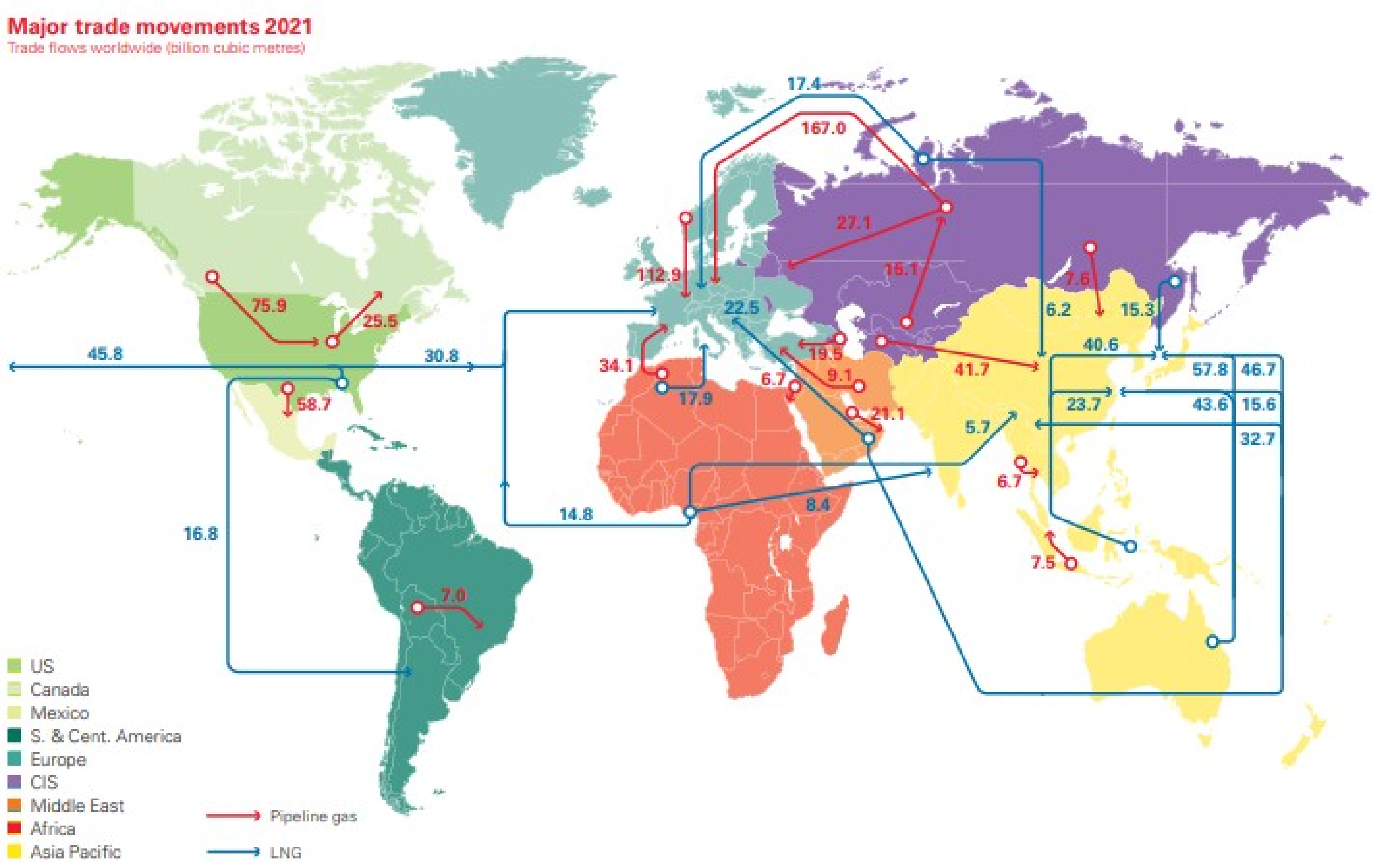
Dolphin Energy

Costs incurred to transport primary energy sources in US$ per tonne of oil equivalent



The economics of gas are driven by its logistics

Gas trade movements - 2021



Major trade movements 2021

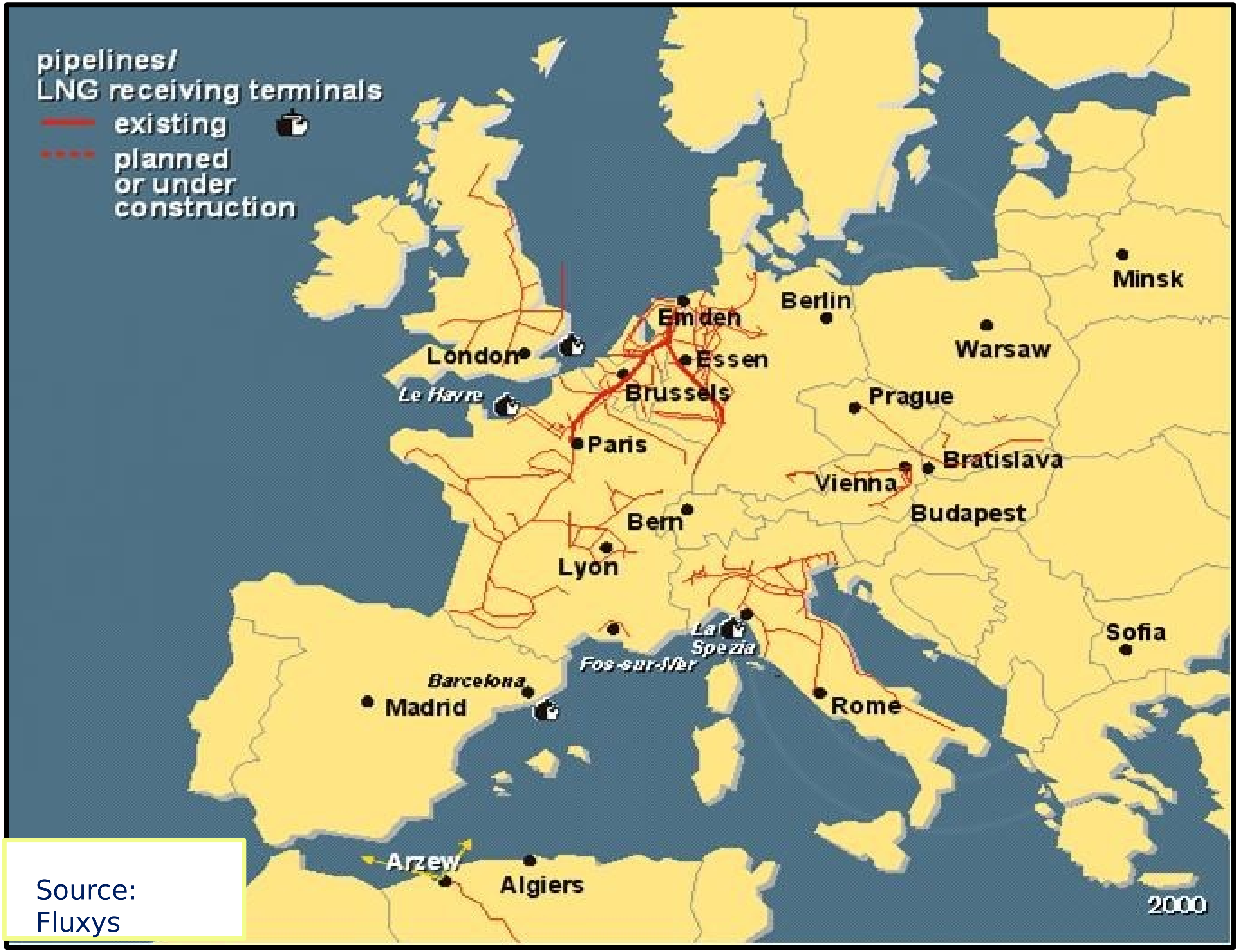
Trade flows worldwide (billion cubic metres)

17.4
167.0
27.1
15.1
112.9
22.5
7.6
6.2
15.3
40.6
75.9
25.5
45.8
30.8
19.5
34.1
9.1
6.7
41.7
57.8
46.7
17.9
23.7
43.6
15.6
58.7
21.1
5.7
32.7
6.7
8.4
14.8
16.8
7.5
7.0
US
Canada
Mexico
S. & Cent. America
Europe
CIS
Middle East
Africa
Asia Pacific
Pipeline gas
LNG

- **Gas is more difficult to trade than oil / coal because it is gas and requires pressure and other conditions**
- 2 major ways to transport natural gas: 1) pipeline; 2) LNG through vessels.
- Pipelines are used in major producers near consumers (the US, Russia, Europe).
- **However, it is LNG which is globalizing the gas market due to its flexibility, allowing overseas trade.**
- The major LNG exchanges are in the Asian Pacific basin and from Middle East to other markets.
- The major pipelines exchanges are between Russia and Europe and in North America.

Transmission Grid 1970

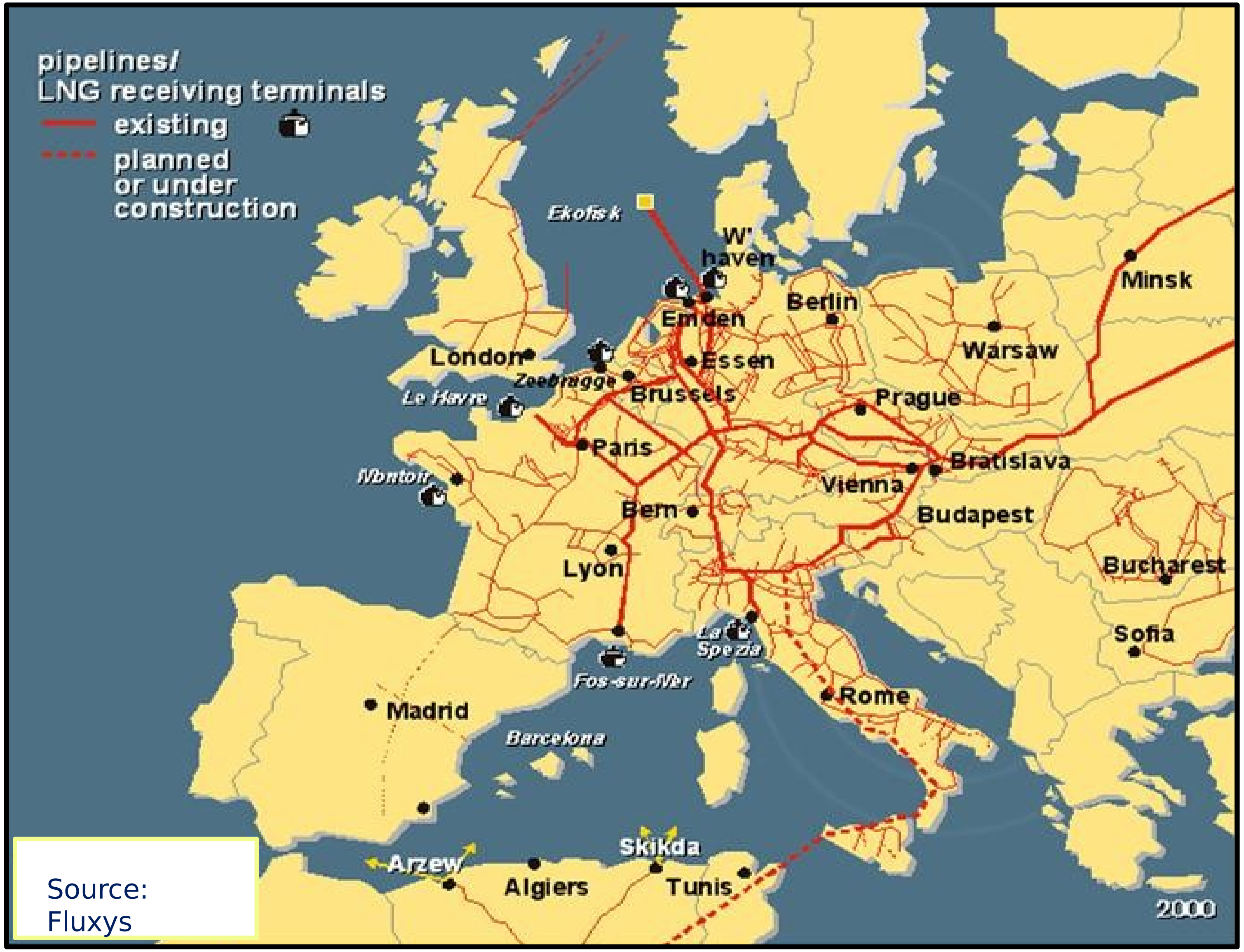
Around Groningen…


pipelines/
LNG receiving terminals
existing
planned
or under
construction
London
Le Havre
Emden
Essen
Brussels
Paris
Berlin
Warsaw
Minsk
Prague
Bratislava
Vienna
Budapest
Bern
Lyon
La Spezia
Fos-sur-Mer
Barcelona
Madrid
Rome
Sofia
Arzew
Algiers
2000

Source: Fluxys

Transmission Grid 1980

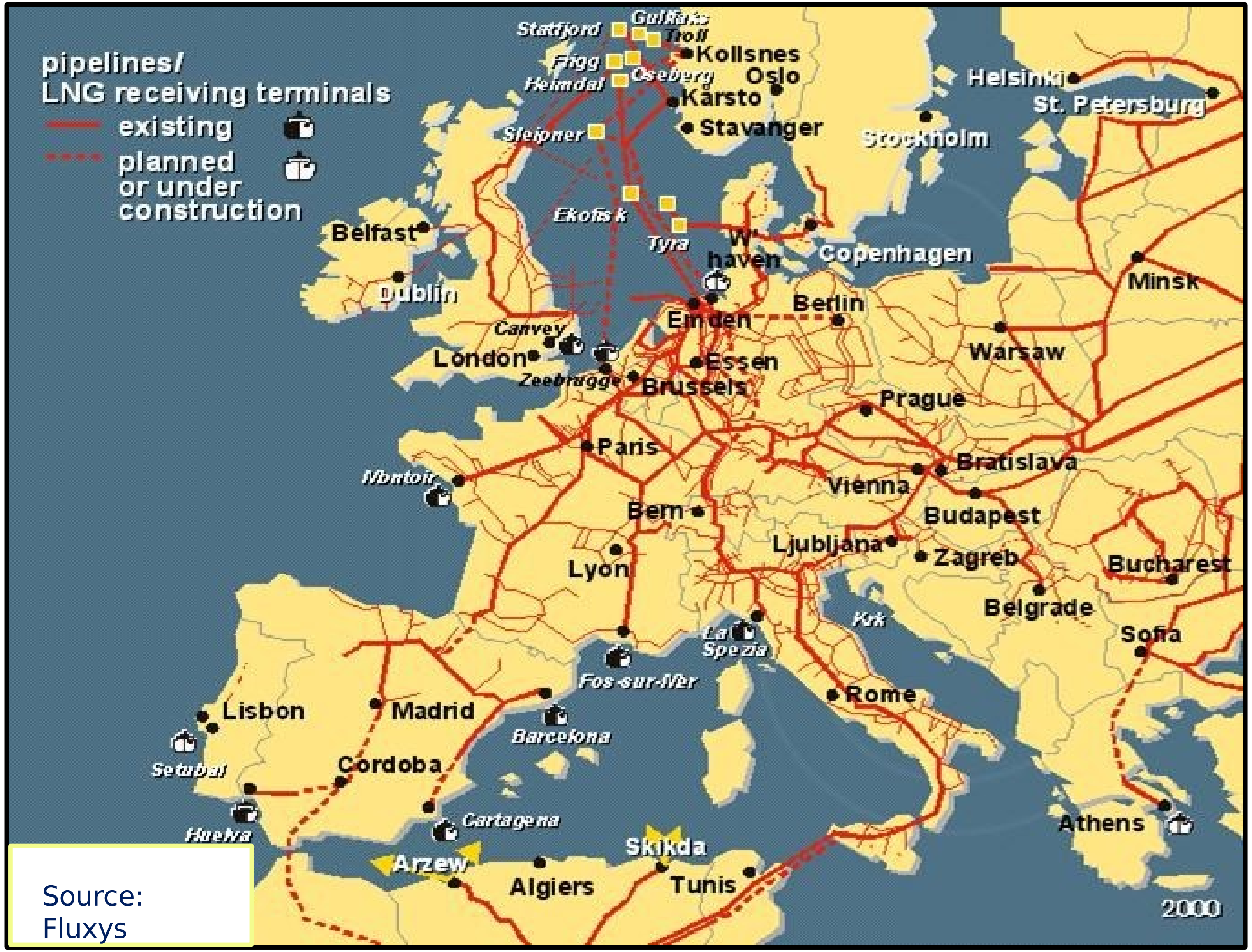
First Soviet Gas…


pipelines/
LNG receiving terminals
existing
planned
or under
construction
Ekofisk
W'
haven
Emden
Berlin
Minsk
Warsaw
London
Essen
Zeebrugge
Brussels
Le Havre
Prague
Paris
Montoir
Bratislava
Vienna
Budapest
Bern
Lyon
Bucharest
La
Spezia
Sofia
Fos-sur-Mer
Rome
Madrid
Barcelona
Skikda
Arzew
Algiers
Tunis
2000

Source:
Fluxys

Transmission Grid 1990

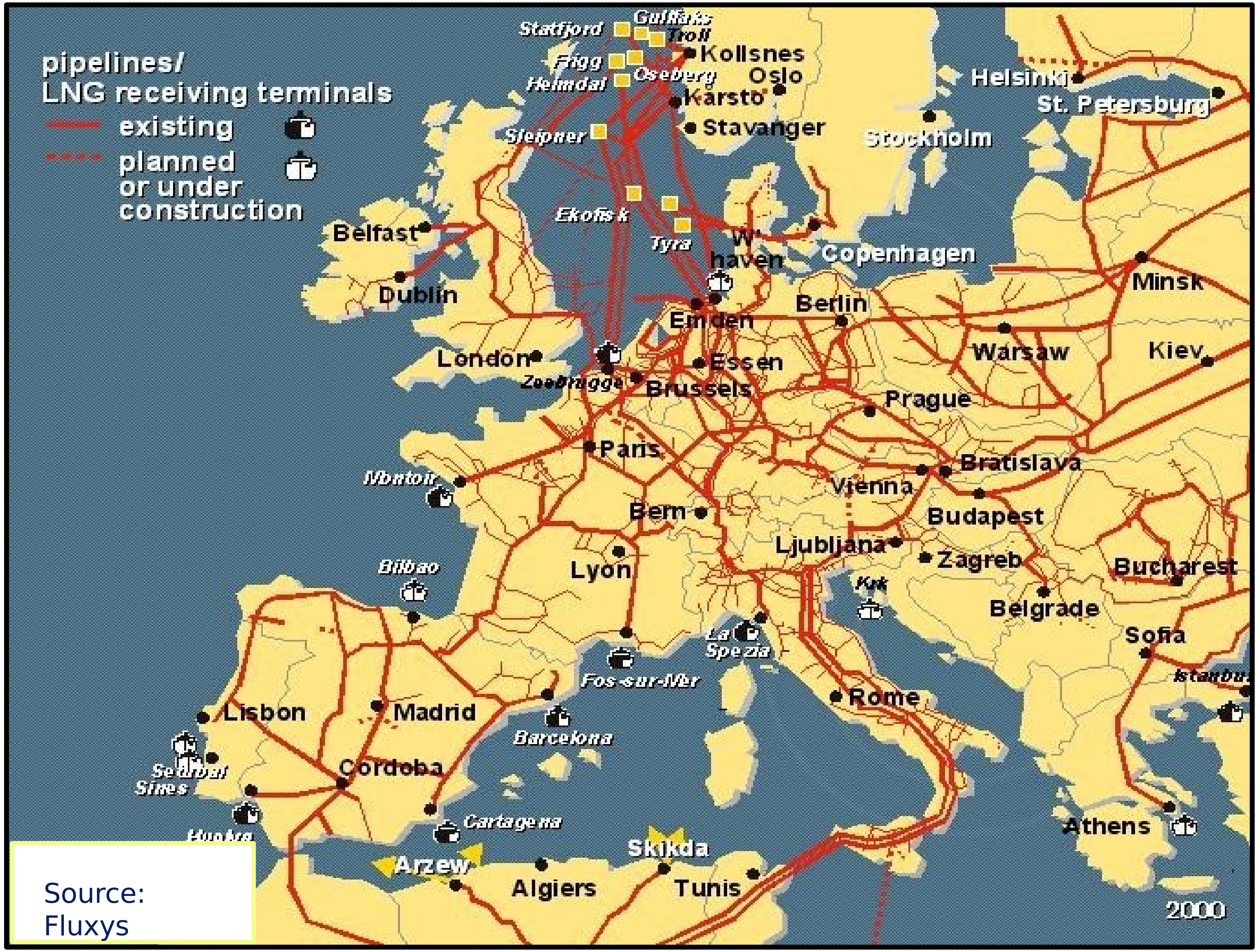
North Sea operations are on line…


pipelines/
LNG receiving terminals
existing
planned
or under
construction
Statfjord
Gullfaks
Troll
Kollsnes
Frigg
Oseberg
Oslo
Heimdal
Kårsto
Sleipner
Stavanger
Helsinki
St. Petersburg
Stockholm
Ekofisk
Tyra
W'
haven
Copenhagen
Belfast
Dublin
Minsk
Berlin
Emden
Canvey
London
Essen
Warsaw
Zeebrugge
Brussels
Prague
Paris
Bratislava
Montoir
Vienna
Bern
Budapest
Ljubljana
Zagreb
Lyon
Bucharest
Belgrade
Krk
La
Spezia
Sofia
Fos-sur-Mer
Rome
Lisbon
Madrid
Barcelona
Setubal
Cordoba
Cartagena
Huelva
Skikda
Athens
Arzew
Algiers
Tunis
2000

Source:
Fluxys

Transmission Grid 2003

More Russian and Algerian gas


pipelines/
LNG receiving terminals
existing
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or under
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Statfjord
Gullfaks
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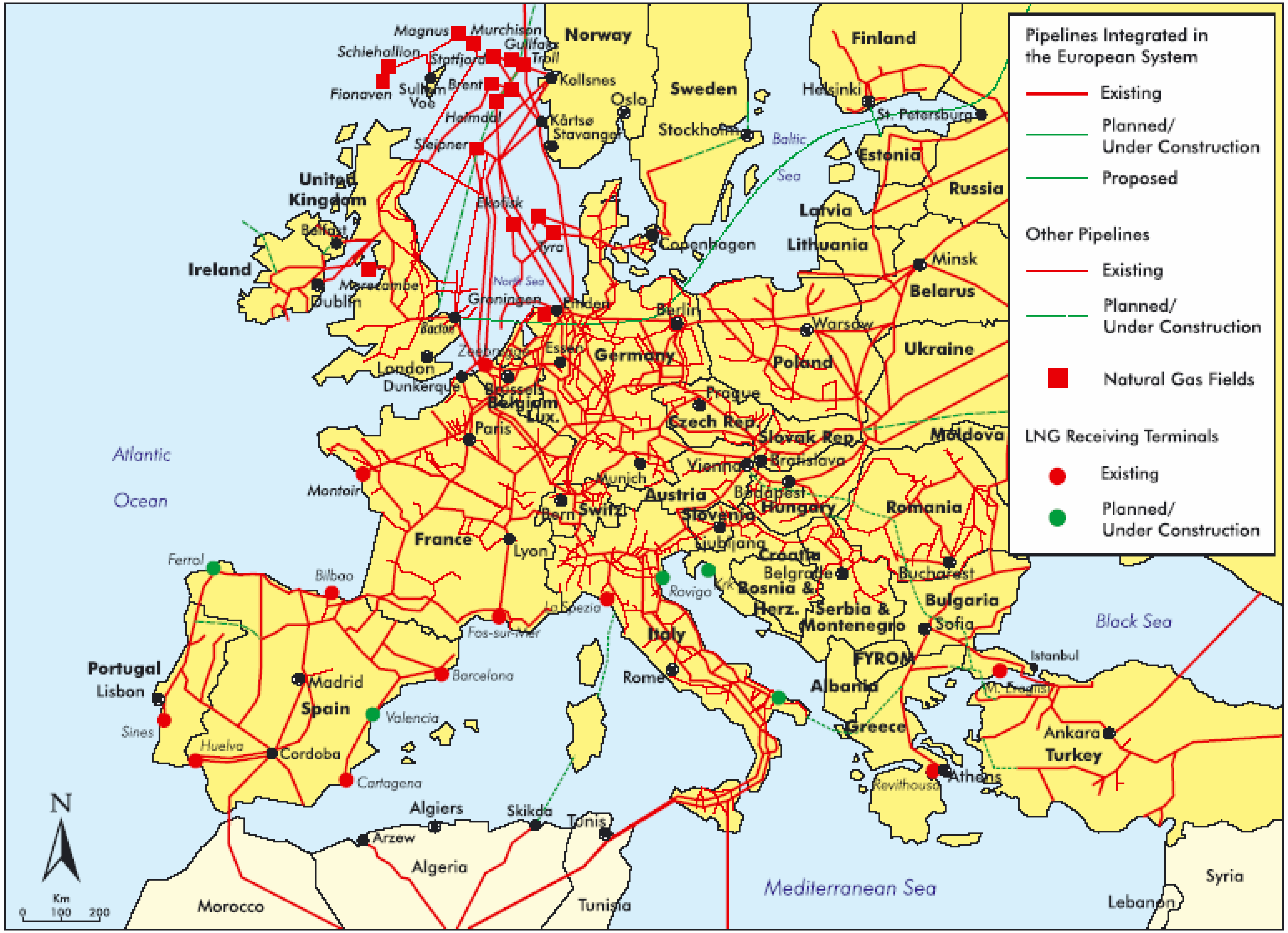
Frigg
Oseberg
Oslo
Heimdal
Karsto
Stavanger
Sleipner
Helsinki
St. Petersburg
Stockholm
Ekofisk
Tyra
W' haven
Copenhagen
Belfast
Dublin
Emden
Berlin
Minsk
Warsaw
Kiev
London
Zeebrugge
Essen
Brussels
Prague
Paris
Montoir
Bratislava
Vienna
Budapest
Bern
Ljubljana
Zagreb
Lyon
Bilbao
Krk
Bucharest
Belgrade
La Spezia
Sofia
Fos-sur-Mer
Istanbu
Rome
Lisbon
Madrid
Barcelona
Cordoba
Setubal
Sines
Huelva
Cartagena
Skikda
Arzew
Algiers
Tunis
Athens
2000

Source:
Fluxys

Transmission Grid 2013

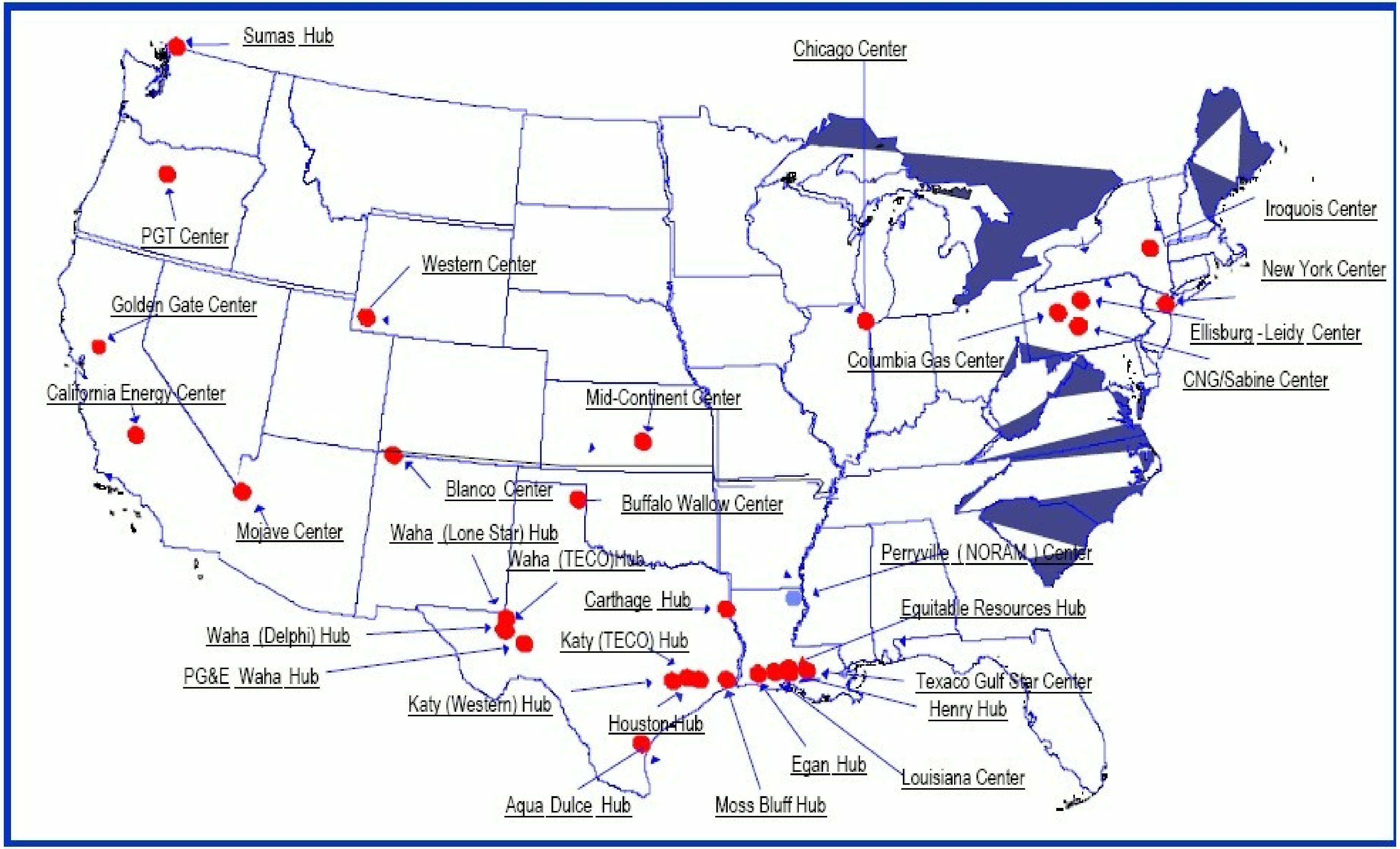
More Russian and Algerian gas


Pipelines Integrated in the European System
Existing
Planned/ Under Construction
Proposed
Other Pipelines
Existing
Planned/ Under Construction
Natural Gas Fields
LNG Receiving Terminals
Existing
Planned/ Under Construction
Magnus
Murchison
Gullfaks
Troll
Schiehallion
Statfjord
Fionaven
Sullom Voe
Brent
Kollsnes
Heimdal
Kårtsø
Stavanger
Sleipner
Ekofisk
Tyra
Norway
Oslo
Sweden
Stockholm
Finland
Helsinki
St. Petersburg
Baltic Sea
Estonia
Russia
Latvia
Lithuania
Minsk
Belarus
Copenhagen
United Kingdom
Belfast
Ireland
Dublin
Morecambe
North Sea
Groningen
Emden
Bacton
London
Zeebrugge
Dunkerque
Essen
Berlin
Warsaw
Poland
Ukraine
Germany
Brussels
Belgium
Lux.
Prague
Czech Rep.
Slovak Rep.
Moldova
Paris
Vienna
Bratislava
Munich
Budapest
Austria
Hungary
Romania
Atlantic Ocean
Montoir
Bern
Switz.
Slovenia
Ljubljana
Croatia
France
Lyon
Ferrol
Bilbao
Belgrade
Bucharest
Ravigo
Krk
Bosnia & Herz.
Serbia & Montenegro
Bulgaria
La Spezia
Fos-sur-Mer
Italy
Sofia
Black Sea
Portugal
Lisbon
Madrid
Spain
Barcelona
FYROM
Istanbul
Rome
Albania
M. Ereglisi
Valencia
Sines
Huelva
Cordoba
Greece
Ankara
Turkey
Athens
Revithousa
Cartagena
N
Algiers
Skikda
Tunis
Arzew
Algeria
Km
0
100
200
Morocco
Tunisia
Mediterranean Sea
Syria
Lebanon

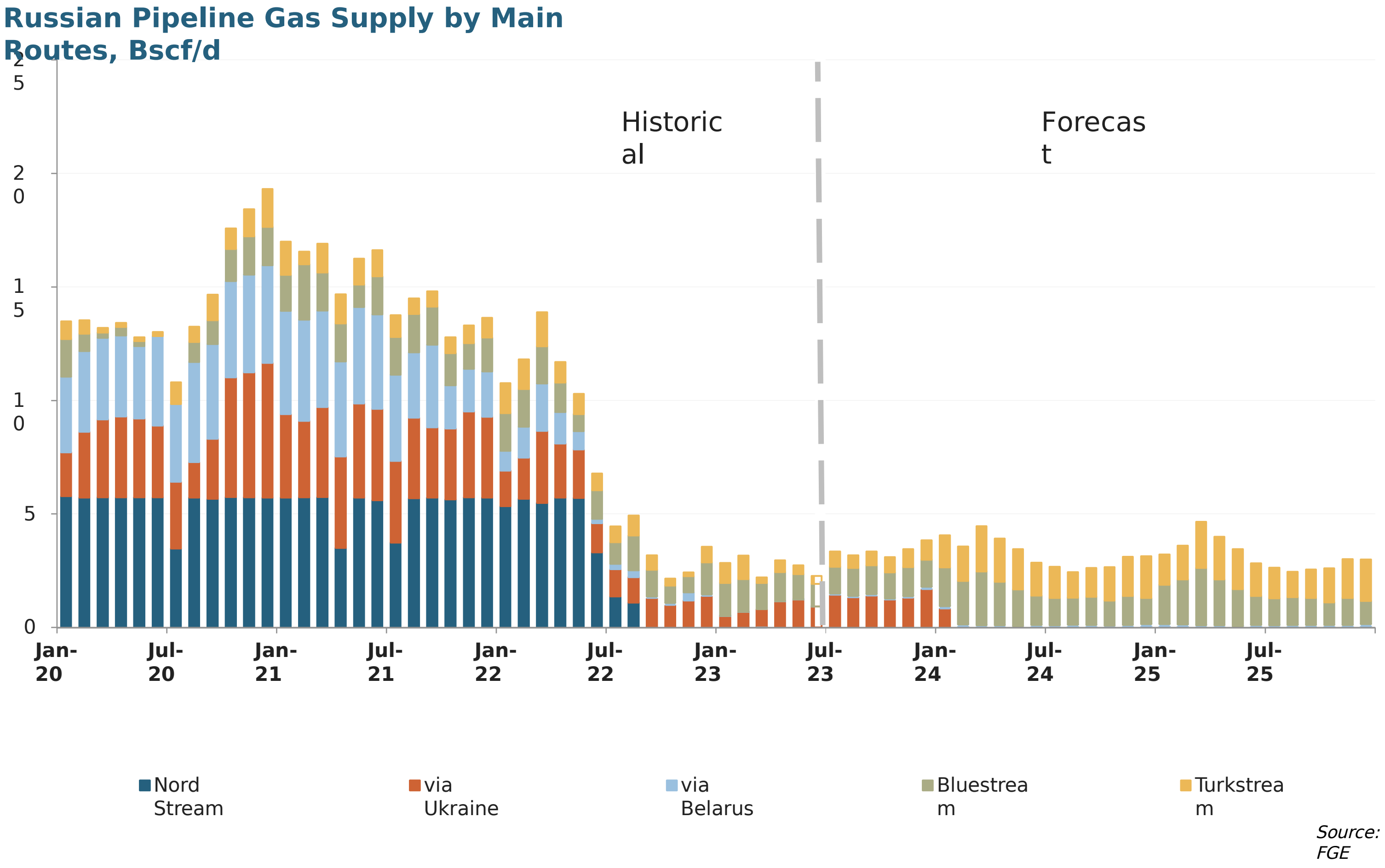
https://www.researchgate.net/figure/Figure-A-2-European-natural-gas-infrastructure_fig5_242448674 [accessed 1 Oct, 2023]

A fully liberalised market

US Gas Hubs


Sumas Hub
Chicago Center
PGT Center
Iroquois Center
Western Center
New York Center
Golden Gate Center
Ellisburg - Leidy Center
Columbia Gas Center
CNG/Sabine Center
California Energy Center
Mid-Continent Center
Blanco Center
Buffalo Wallow Center
Mojave Center
Waha (Lone Star) Hub
Waha (TECO) Hub
Perryville (NORAM) Center
Carthage Hub
Equitable Resources Hub
Waha (Delphi) Hub
Katy (TECO) Hub
PG&E Waha Hub
Texaco Gulf Star Center
Katy (Western) Hub
Henry Hub
Houston Hub
Egan Hub
Louisiana Center
Aqua Dulce Hub
Moss Bluff Hub

Russian gas flows to Europe unlikely to return to pre-war levels

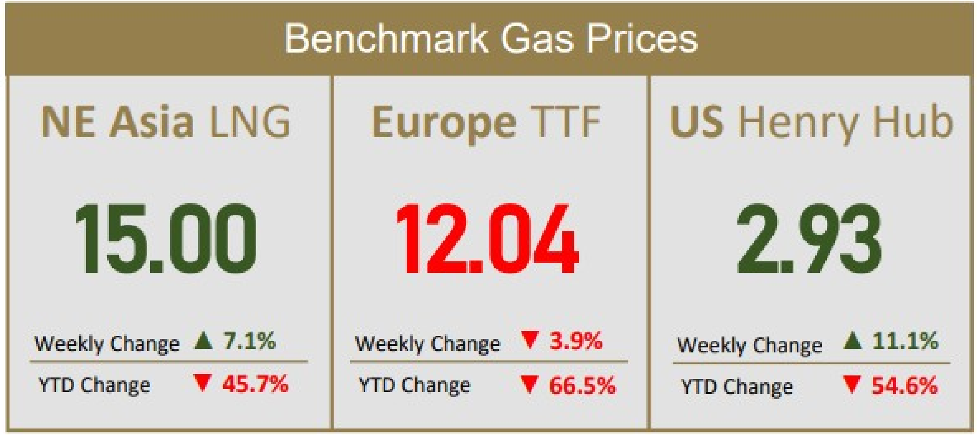


Russian Pipeline Gas Supply by Main Routes, Bscf/d

Source: FGE

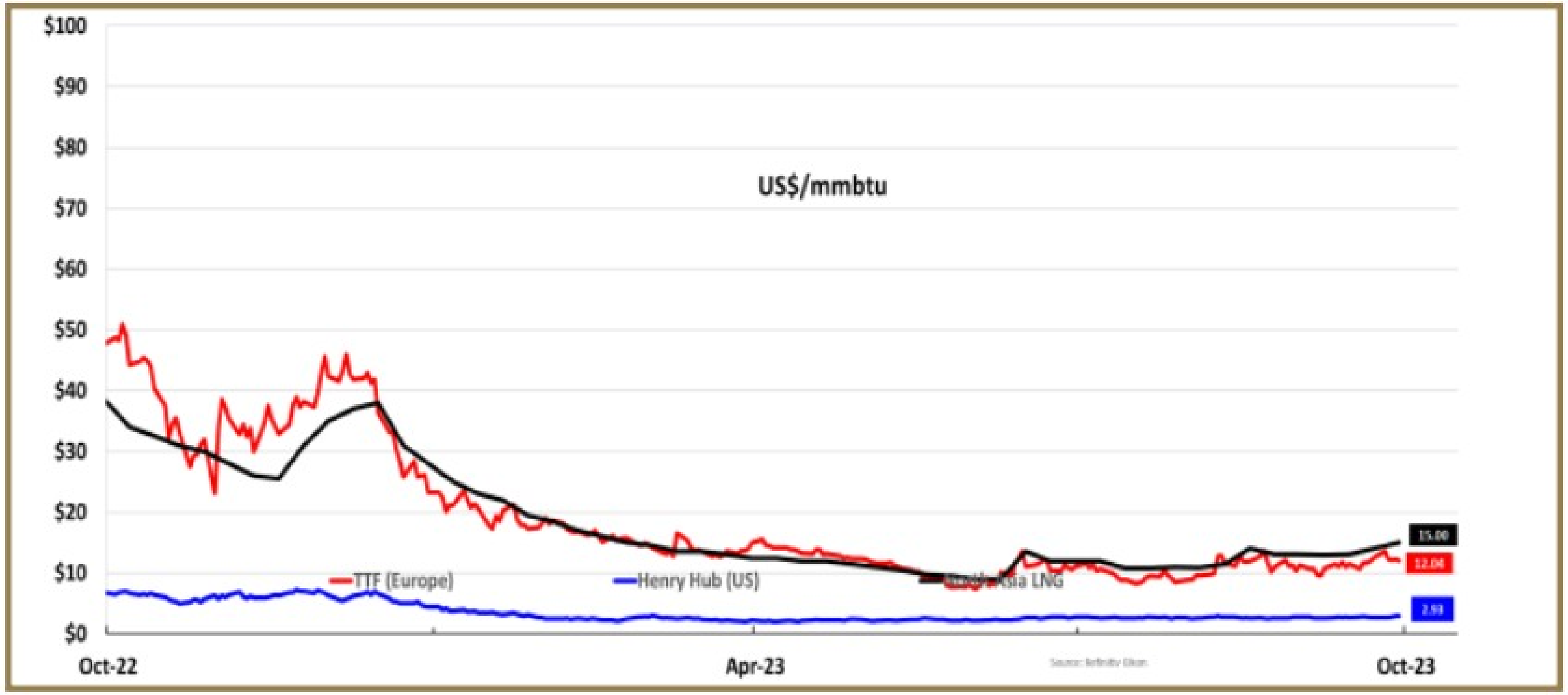
- There is a growing likelihood that the **Ukraine-Russia gas transit deal will not be renewed**, and **Europe will lose Russian pipeline supply** via Ukraine in January 2024.
- Nonetheless, **Russian gas supply to Turkey** (via Blue Stream and Turkstream) is expected to gain further.
- The **EU Commission aims to cut its dependency on Russian gas**, and EU countries are likely to **cease their direct pipeline gas imports from Russia by**

The closing price ($/mmBtu) as of Friday 29 Sep 2023



Benchmark Gas Prices

NE Asia LNG		Europe TTF		US Henry Hub	
15.00		12.04		2.93	
Weekly Change	▲ 7.1%	Weekly Change	▼ 3.9%	Weekly Change	▲ 11.1%
YTD Change	▼ 45.7%	YTD Change	▼ 66.5%	YTD Change	▼ 54.6%

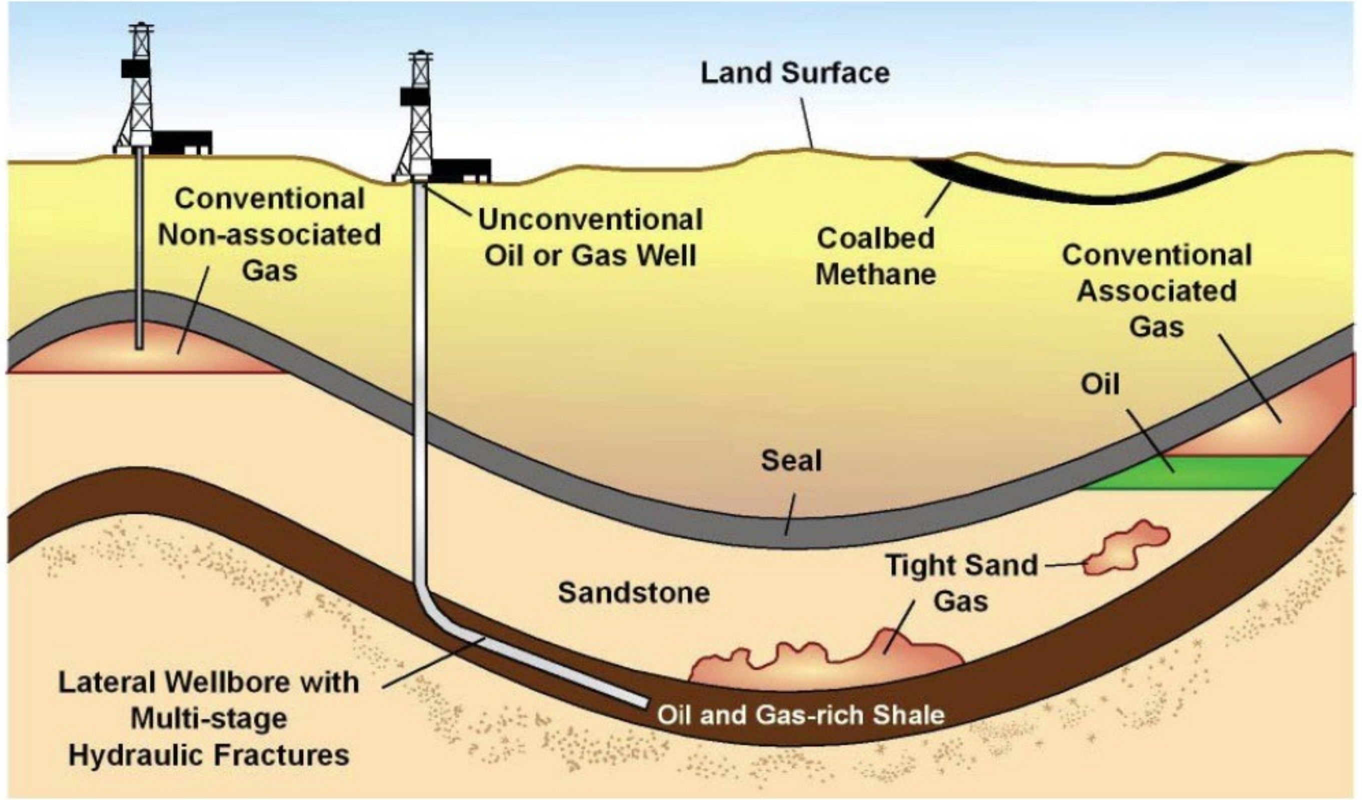


Weekly Energy market review
The Abdullah Bin Hamad Al-Attiyah International Foundation

The unconventional fossil fuels

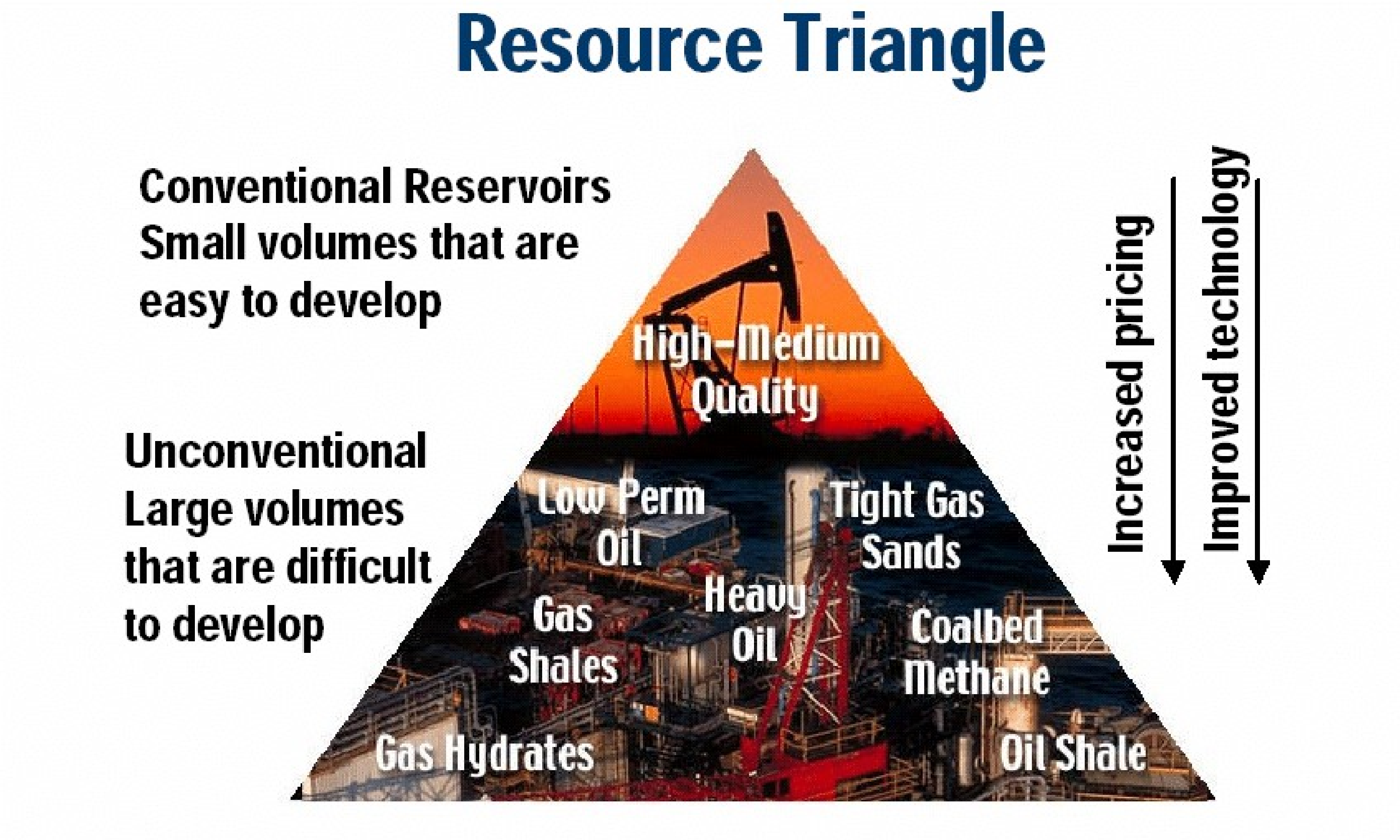
- Unconventional fossil fuels are energy resources which were non-commercial because they were both technical challenging and more expensive in their production.
- **They are mainly four: tar sands, oil shale, shale gas and deep-water oil**, though there are some other potential resources in the future.
- **These unconventional fossil fuels are re-increasing reserves in different parts of the world.**
- They are a expression of the market innovations, when lack of reserves and energy demand drives research and policy to unlock resources previously not considered attractive to exploit

The Geology of Conventional and Unconventional Oil and Gas


Land Surface
Conventional Non-associated Gas
Unconventional Oil or Gas Well
Coalbed Methane
Conventional Associated Gas
Oil
Seal
Sandstone
Tight Sand Gas
Lateral Wellbore with Multi-stage Hydraulic Fractures
Oil and Gas-rich Shale

Source: EIA

Challenges and benefits from the unconventional resources


Resource Triangle
Conventional Reservoirs
Small volumes that are
easy to develop
Unconventional
Large volumes
that are difficult
to develop
High-Medium
Quality
Low Perm
Oil
Tight Gas
Sands
Gas
Shales
Heavy
Oil
Coalbed
Methane
Gas Hydrates
Oil Shale
Increased pricing
Improved technology

Advantages of fossil fuels

Energy density:

FFs are globally used because of the large quantities of energy they release from a small volume of any of them. For instance, how many miles may you go with one liter of gasoline?

Low productive costs: until very recently, producing coal, oil and gas was extremely cheap. Indeed it is still, but as the shallower and less challenging reserves are depleted, costs are increasing with other resources (unconventional).

Low cost of associated products and services:

The products from the refining of oil and natural gas are based on industrial processes known for decades, with affordable costs for the demand and well commercialized in all the aspects of our life. It is the same with the energy services we can get from them (power, heat, transportation, home heating, etc.)

Infrastructure and technology:

Fossil fuels have been used for decades. Both the infrastructure to explore, discover and produce is already in place, the technology that makes it possible is very mature and enhancing with time.

A vast number of outlook scenario

Approaches towards modelling the world energy outlook vary markedly

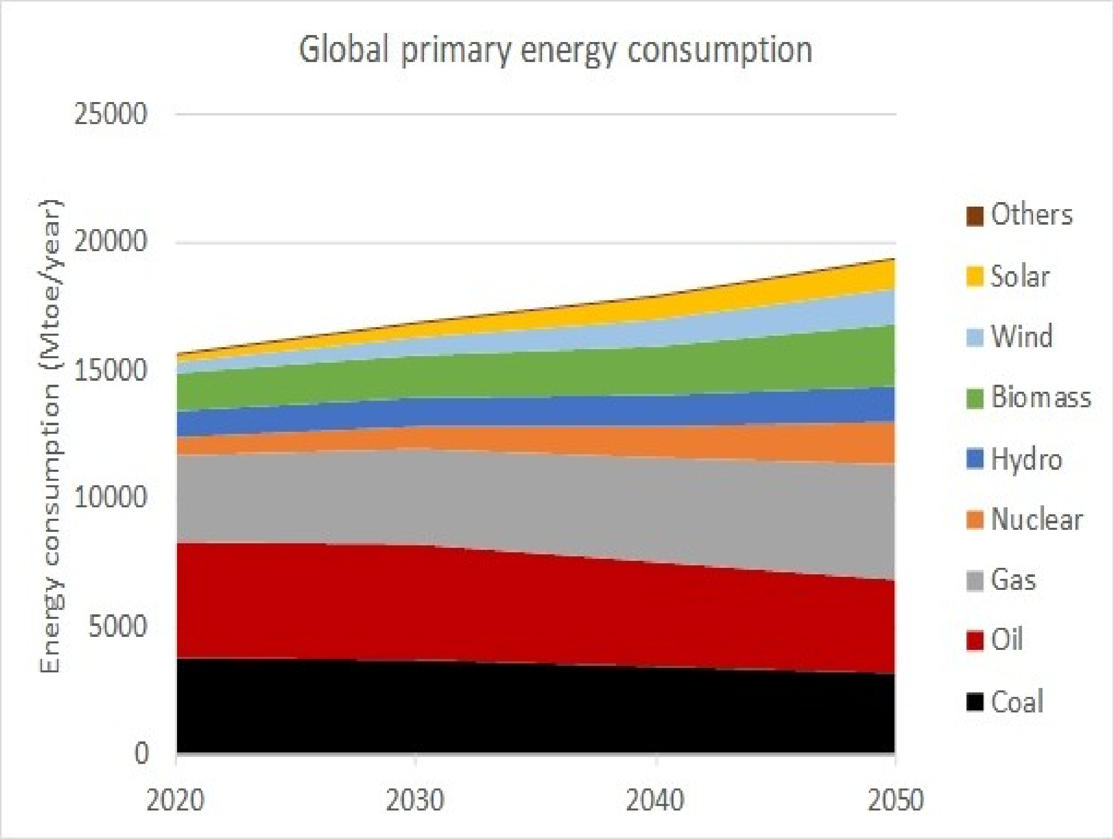
However, no scenario is meant to be a forecast. Scenario are projected trends

MODELLING	iea International Energy Agency	eia	IEE JAPAN		
STORY-TELLIN	WORLD ENERGY COUNCIL CONSEIL MONDIAL DE L'ÉNERGIE For sustainable energy.	CENTRAL INTELLIGENCE AGENCY UNITED STATES OF AMERICA			
CORPORATE	bp	eni			
NATIONAL	RAPPORT énergies 2050	energy roadmap 2050			
MACRO MODEL	OECD				

Do you consider fossil fuels as SUSTAINABLE or UNSUSTAINABLE ?

3 main issues

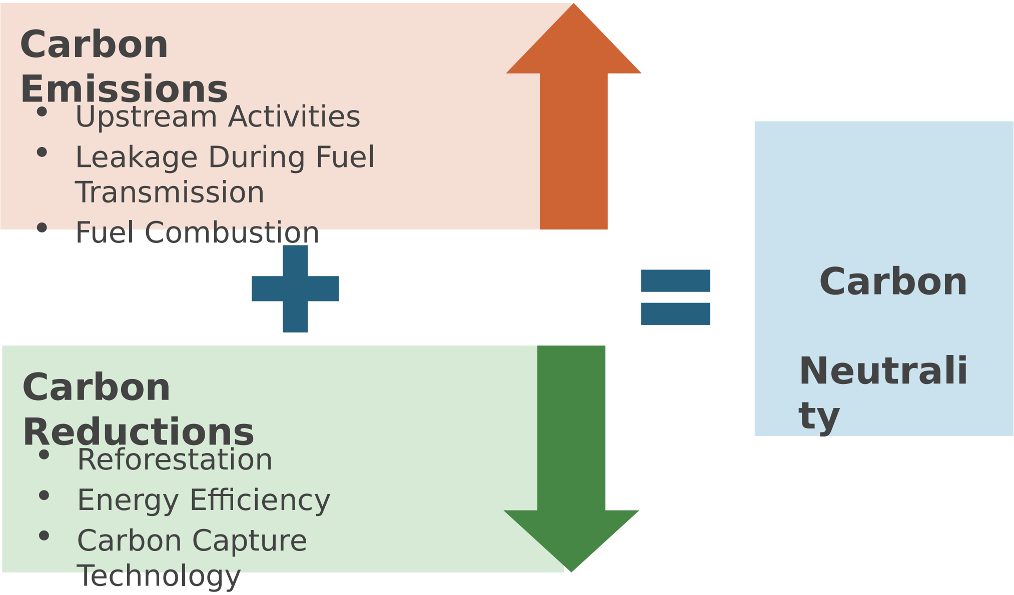
1. **Fossil fuels are finite**, they take geological times to regenerate, so they are, non-renewable in human terms
2. **Fossil fuels emit pollutants**, which are detrimental to the environment, the more worrying, the carbon emissions, which threat to alter the global climate.
3. **We depend between 80% t0 85% of our energy primary sources on fossil fuels**. It is necessary to set some diversification in such high dependence.



- **The solution is not to stop their use right away**. We cannot do that even if we wanted. Instead, we **should phase them out progressively and in a responsible fashion**.
- The role of fossil fuels in the future stands in providing energy, but **controlling their massive carbon emissions and impacts.**
- At the same time, we should **provide a clear pathway towards renewable energies**, leading to fossil fuels phasing out in some decades.

Important Emerging Issue:

Carbon Neutral LNG



Carbon Emissions

- Upstream Activities
- Leakage During Fuel Transmission
- Fuel Combustion

+

Carbon Reductions

- Reforestation
- Energy Efficiency
- Carbon Capture Technology

=

Carbon Neutrality

Carbon Neutrality Equation

- A carbon neutral LNG deal involves two components: a typical LNG supply deal, and **carbon offsets that reduce carbon emissions equivalent to the emissions that would have occurred from consuming the LNG**.
- Carbon neutrality comes at a premium.
- **Carbon offsets are still a developing market**, with more standardization required in the areas of accounting and pricing.

Seller

MITSUI&CO.
bp
PETRONAS
RWE
Jera Global Markets
eni
INPEX
GAZPROM
Oman LNG L.L.C.
Naturgy
DIAMOND GAS INTERNATIONAL

Buyer

posco
TOKYO GAS
PAVILION ENERGY
CNOOC
PetroChina
TOHO GAS
GS Energy
SHIKOKU ELECTRIC POWER
SHIZGAS
OSAKA GAS
台灣中油股份有限公司 CPC Corporation, Taiwan

FUTURE
READY

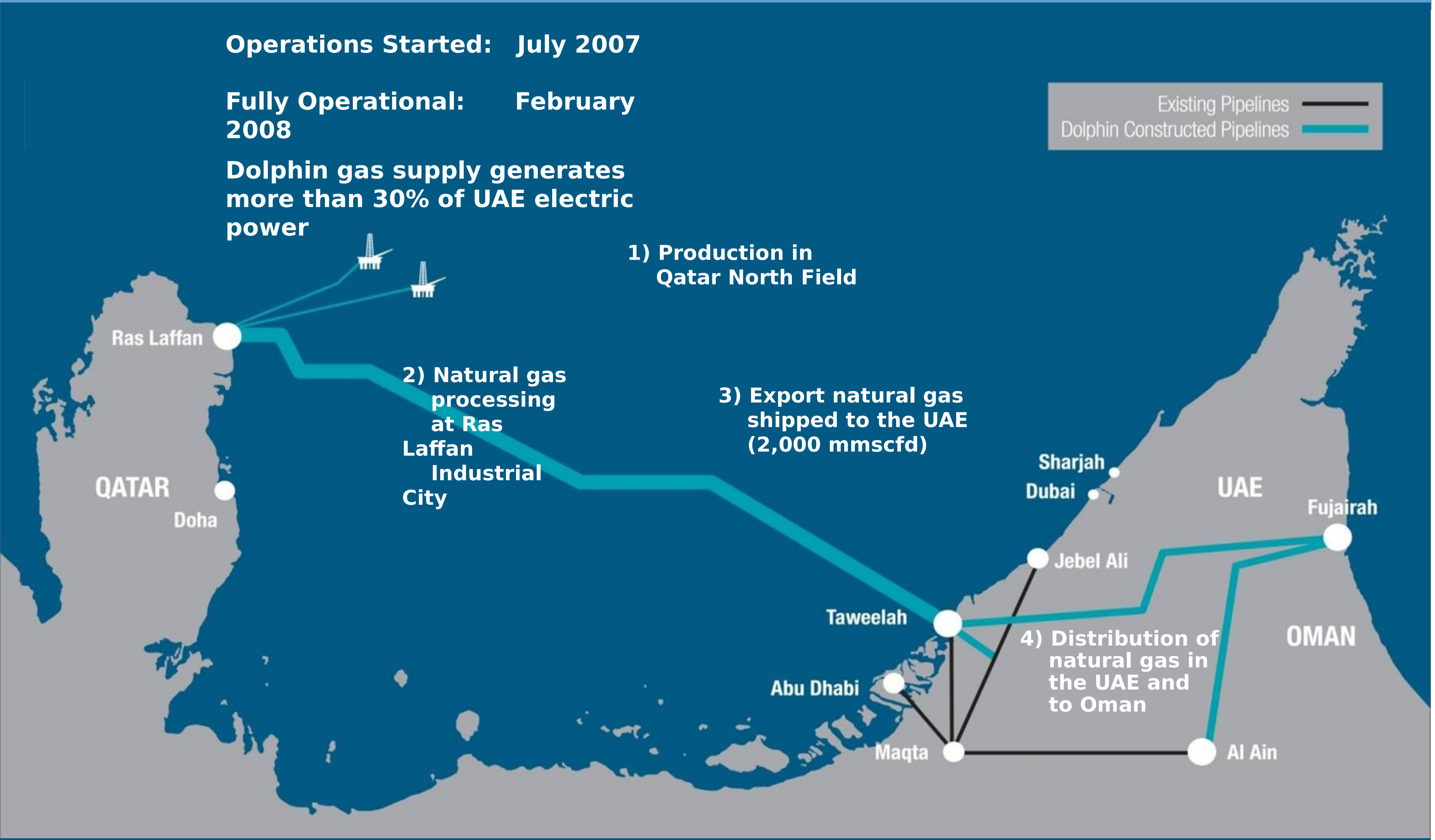
DOLPHIN ENERGY
دولفين للطاقة

Dolphin Energy Facilities Overview

Operations Started: July 2007

Fully Operational: February 2008

Dolphin gas supply generates more than 30% of UAE electric power


Existing Pipelines
Dolphin Constructed Pipelines
Ras Laffan
QATAR
Doha
Sharjah
Dubai
UAE
Fujairah
Jebel Ali
Taweelah
OMAN
Abu Dhabi
Maqta
Al Ain

1) Production in Qatar North Field

2) Natural gas processing at Ras Laffan Industrial City

3) Export natural gas shipped to the UAE (2,000 mmscfd)

4) Distribution of natural gas in the UAE and to Oman

مبادلة
MUBADALA

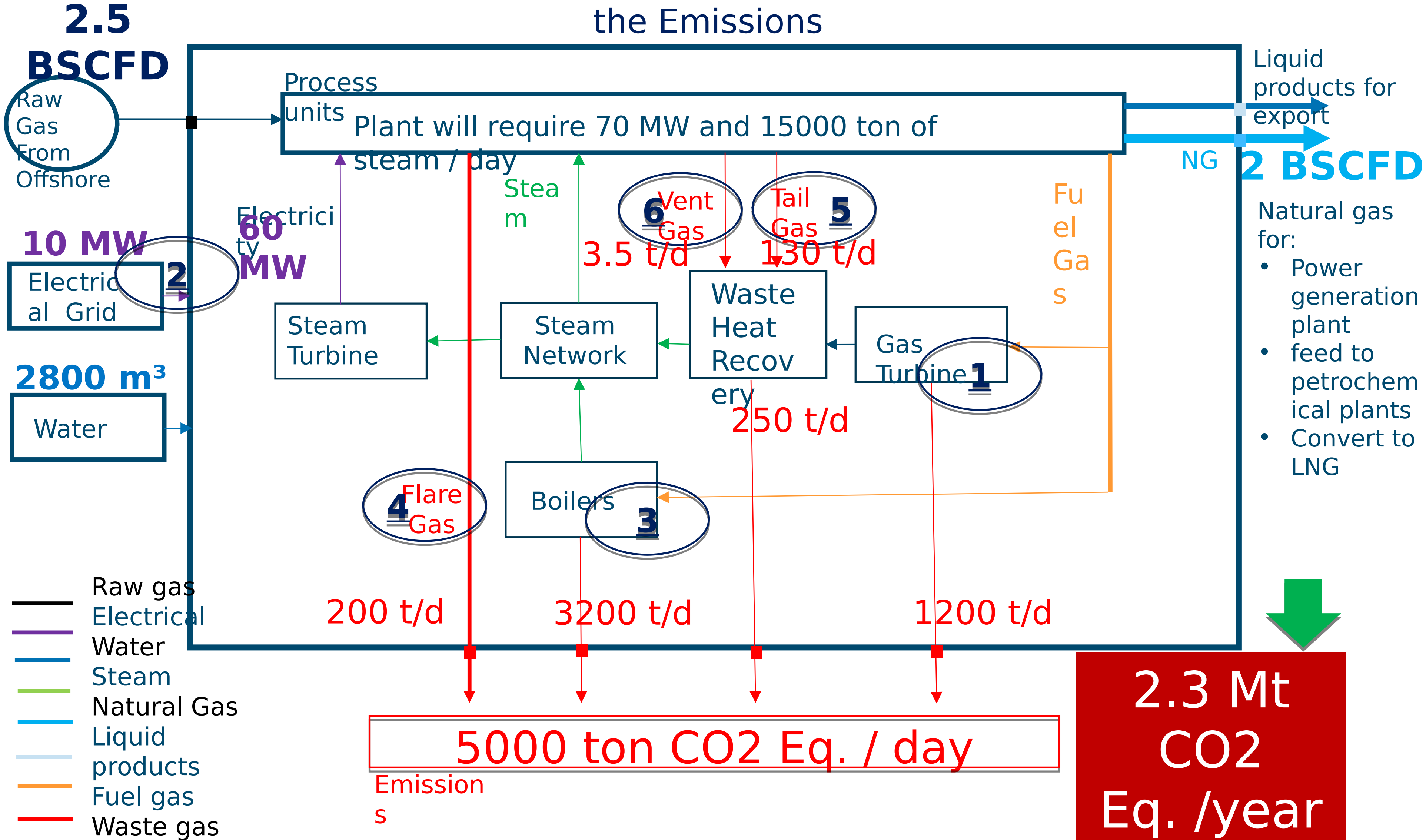
TOTAL

OXY

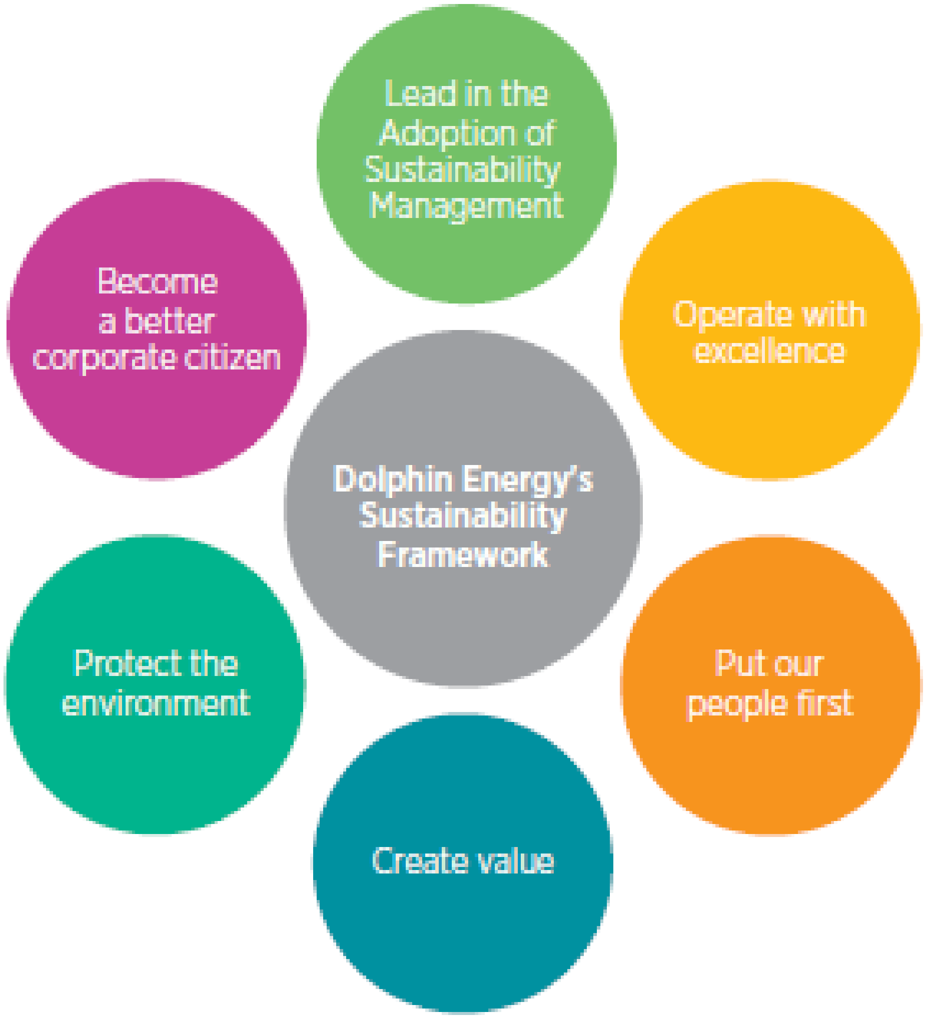
n Energy is a fully integrated energy initiative that connects natural gas reserves in Qatar’s North F end markets in the UAE and Oman

1. Introduction : Area of

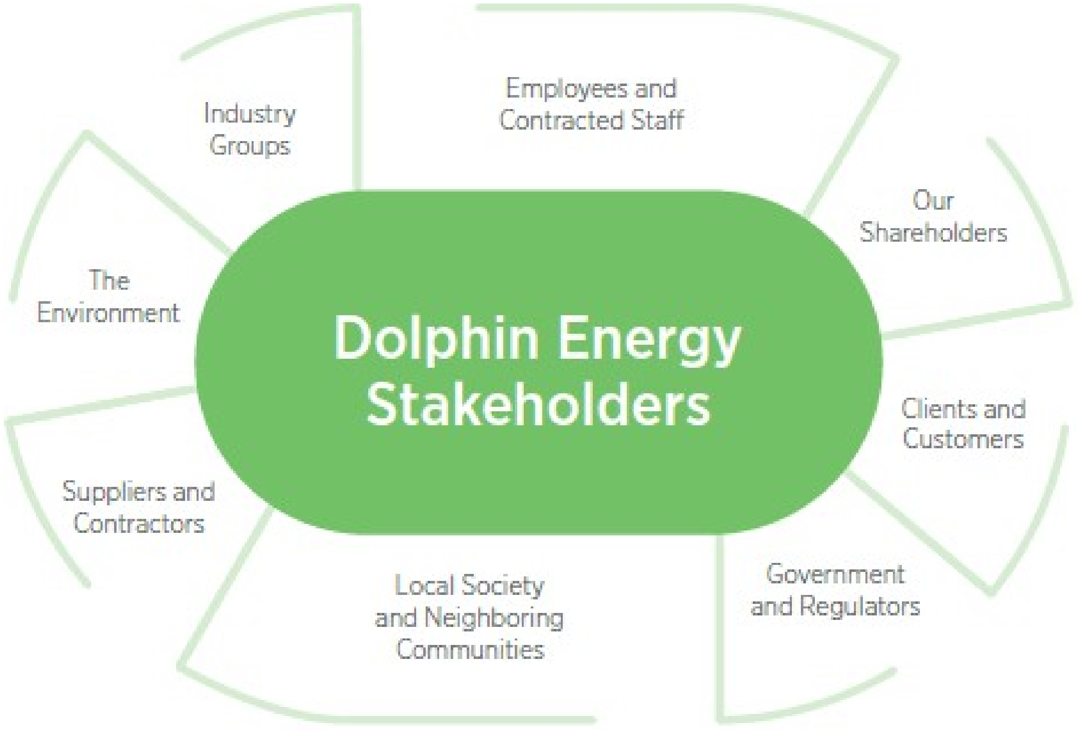
Areas of Improvement to Increase the Efficiency and Decrease the Emissions


2.5 BSCFD
Raw Gas From Offshore
Process units
Plant will require 70 MW and 15000 ton of steam / day
Liquid products for export
NG
2 BSCFD
Natural gas for:
• Power generation plant
• feed to petrochemical plants
• Convert to LNG
10 MW
Electrical Grid
2
Electricity
60 MW
2800 m³
Water
Steam
Steam Turbine
Steam Network
6
Vent Gas
3.5 t/d
Tail Gas
5
130 t/d
Waste Heat Recovery
250 t/d
Fuel Gas
Gas Turbine
1
4
Flare Gas
Boilers
3
200 t/d
3200 t/d
1200 t/d
5000 ton CO2 Eq. / day
Emissions
2.3 Mt CO2 Eq. /year
Raw gas
Electrical
Water
Steam
Natural Gas
Liquid products
Fuel gas
Waste gas

ommitments to Clean Energy and Sustainability


Dolphin Energy's Sustainability Framework
Lead in the Adoption of Sustainability Management
Operate with excellence
Put our people first
Create value
Protect the environment
Become a better corporate citizen

All it takes is Positive Energy


Dolphin Energy Stakeholders
Industry Groups
Employees and Contracted Staff
Our Shareholders
Clients and Customers
Government and Regulators
Local Society and Neighboring Communities
Suppliers and Contractors
The Environment

Dolphin Energy Annual Sustainability report of year 2022:
www.sustainability.dolphinenergy.com

Sustainability Report 2022

Highlights

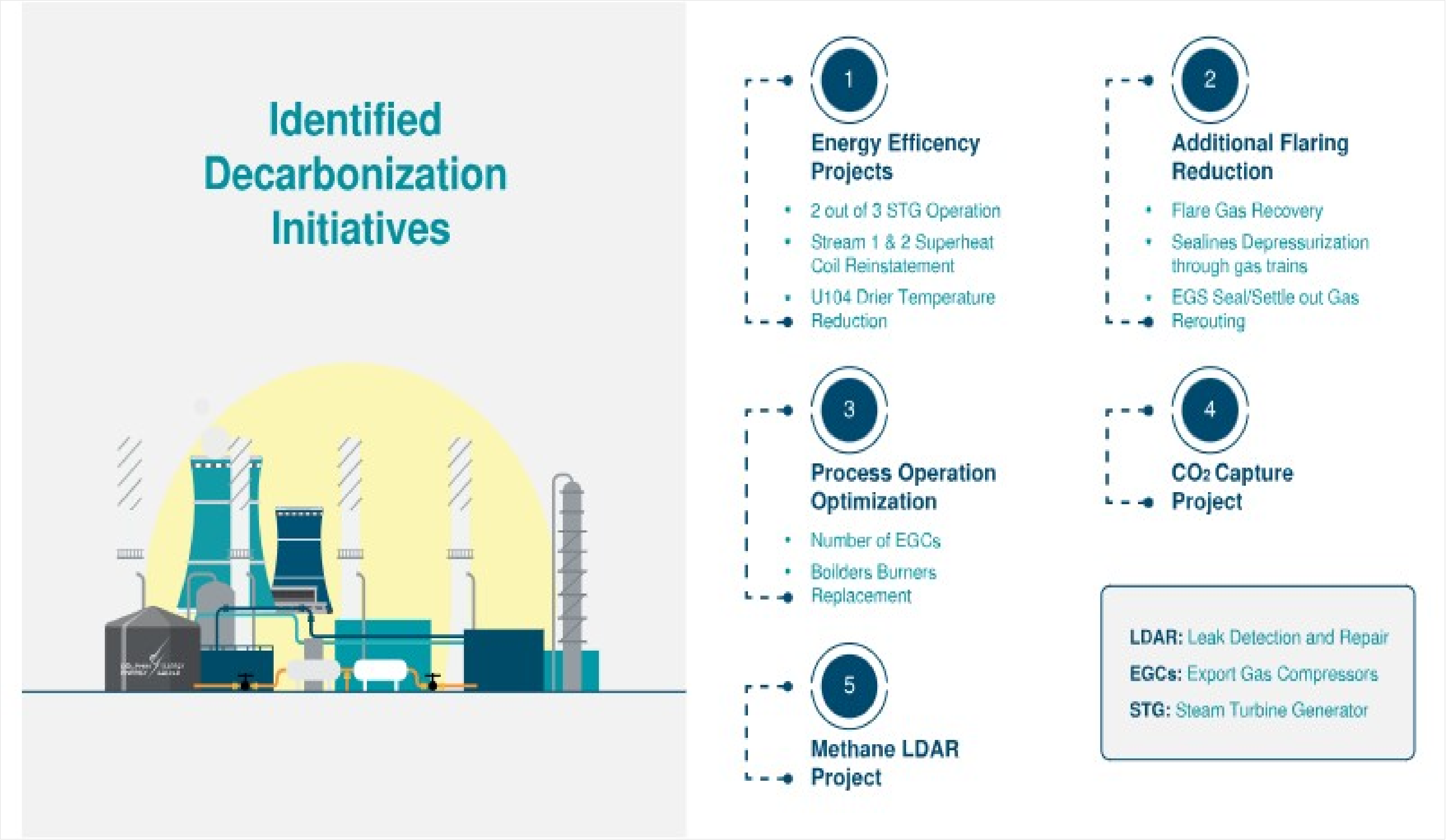
- 13% increase, total environmental expenditure
- 1.2% reduction, total greenhouse gas emissions
- 81% reduction, gas venting
- 1.7% reduction, direct energy consumption
- 14.7% reduction, water consumption
- ZERO recordable spills

"Each year, we raise our standards of environmental excellence by collaborating with our peers and expert environmental partners, creating a culture of environmental responsibility that benefits us all. We are committed to complying with regulations in both Qatar and the UAE, preventing and minimizing potential environmental impacts of our actions and decisions, and monitoring and reporting progress towards our environmental goals."

Dr. Rola Atiyeh, Senior Manager Environment and Sustainability

Decarbonization Roadmap

“This comprehensive ***decarbonization roadmap*** *marks a milestone in our* ***sustainable development contribution to the Gulf region*** *and beyond. It sets a clear path to* ***measure, manage, report, and reduce our GHG emissions****, both upstream and downstream. With strong* ***governance and accountability*** *for delivery, we will* ***embrace technologies and cultural programs*** *that accelerate our advancement* ***towards net zero carbon****. In doing*



Identified Decarbonization Initiatives

1 **Energy Efficency Projects**

- 2 out of 3 STG Operation
- Stream 1 & 2 Superheat Coil Reinstatement
- U104 Drier Temperature Reduction

2 **Additional Flaring Reduction**

- Flare Gas Recovery
- Sealines Depressurization through gas trains
- EGS Seal/Settle out Gas Rerouting

3 **Process Operation Optimization**

- Number of EGCs
- Boilders Burners Replacement

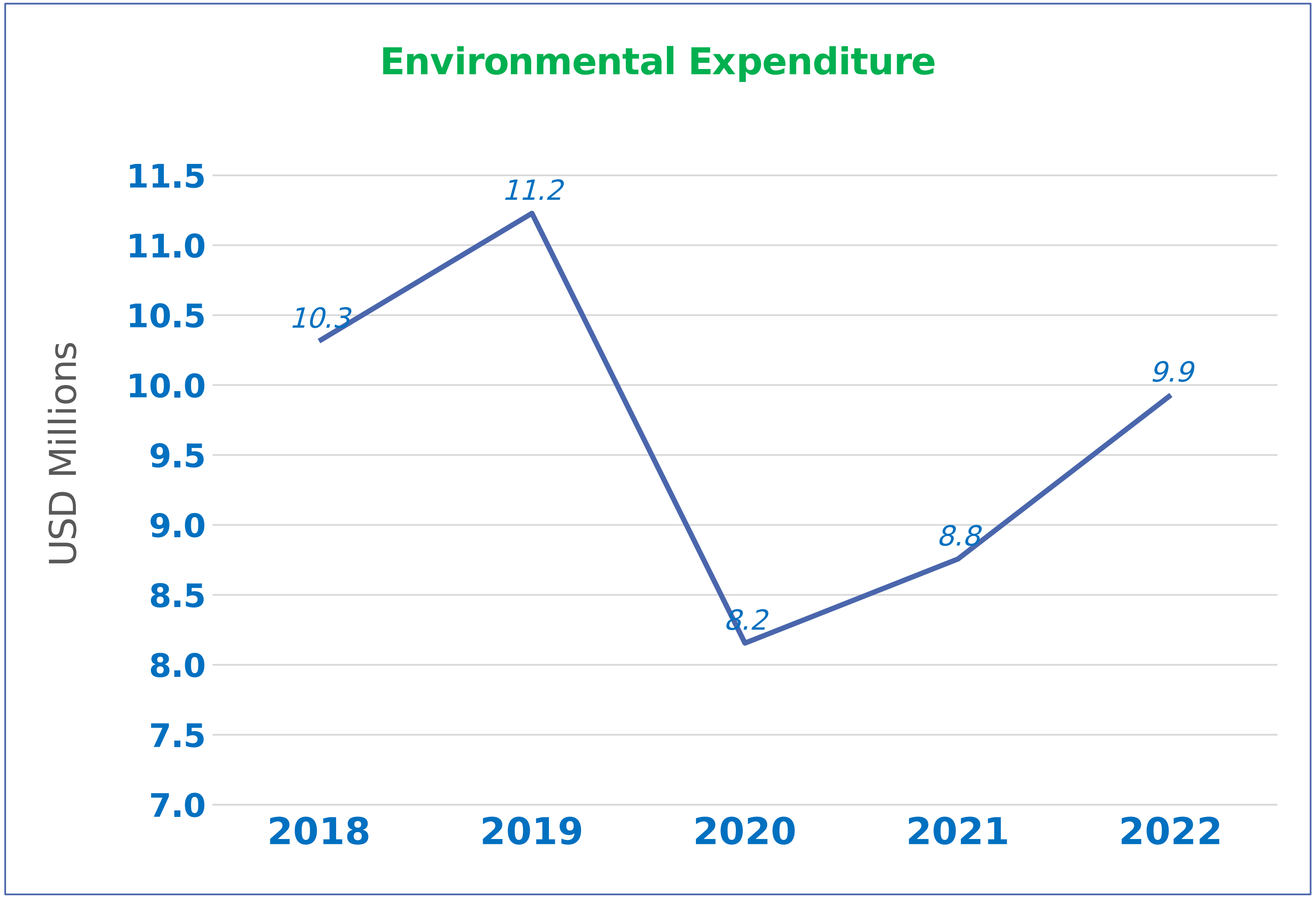
4 **CO_2 Capture Project**

5 **Methane LDAR Project**

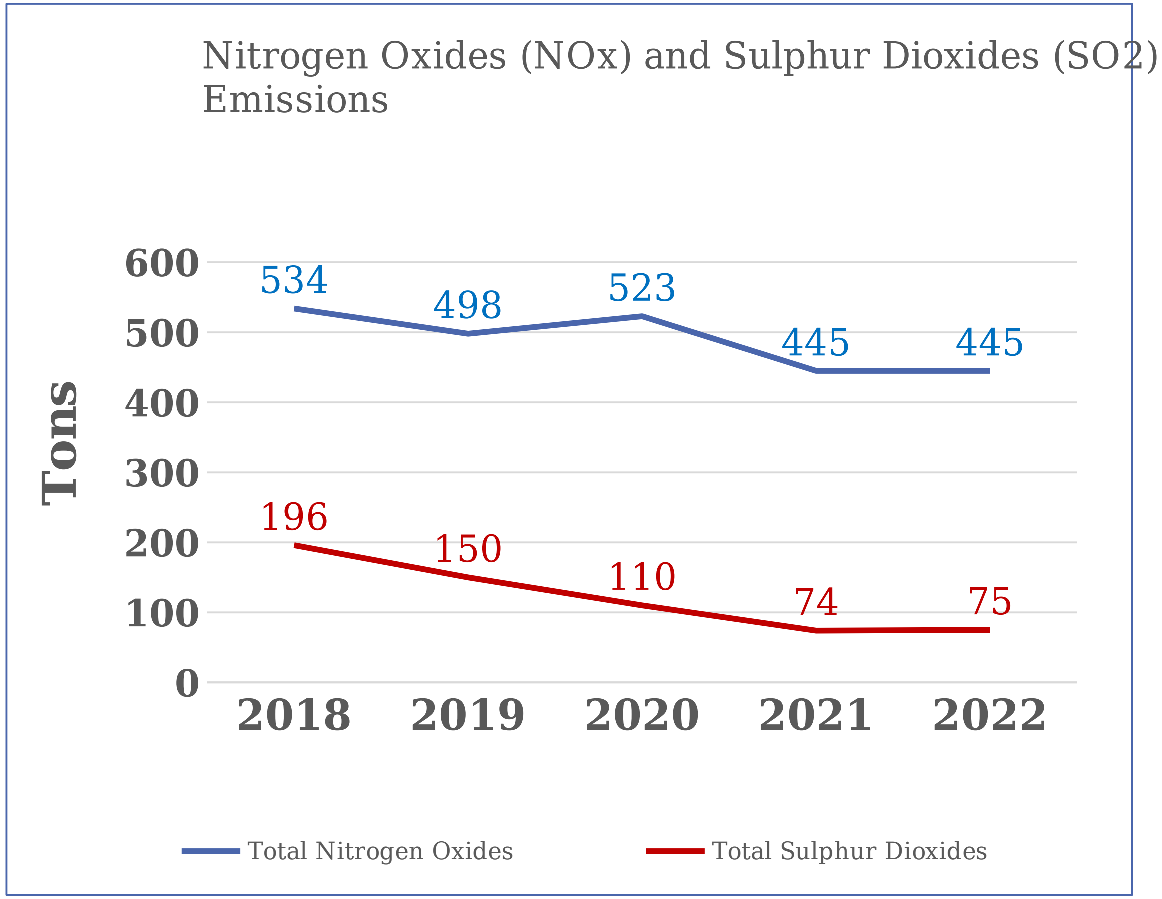
LDAR: Leak Detection and Repair
EGCs: Export Gas Compressors
STG: Steam Turbine Generator

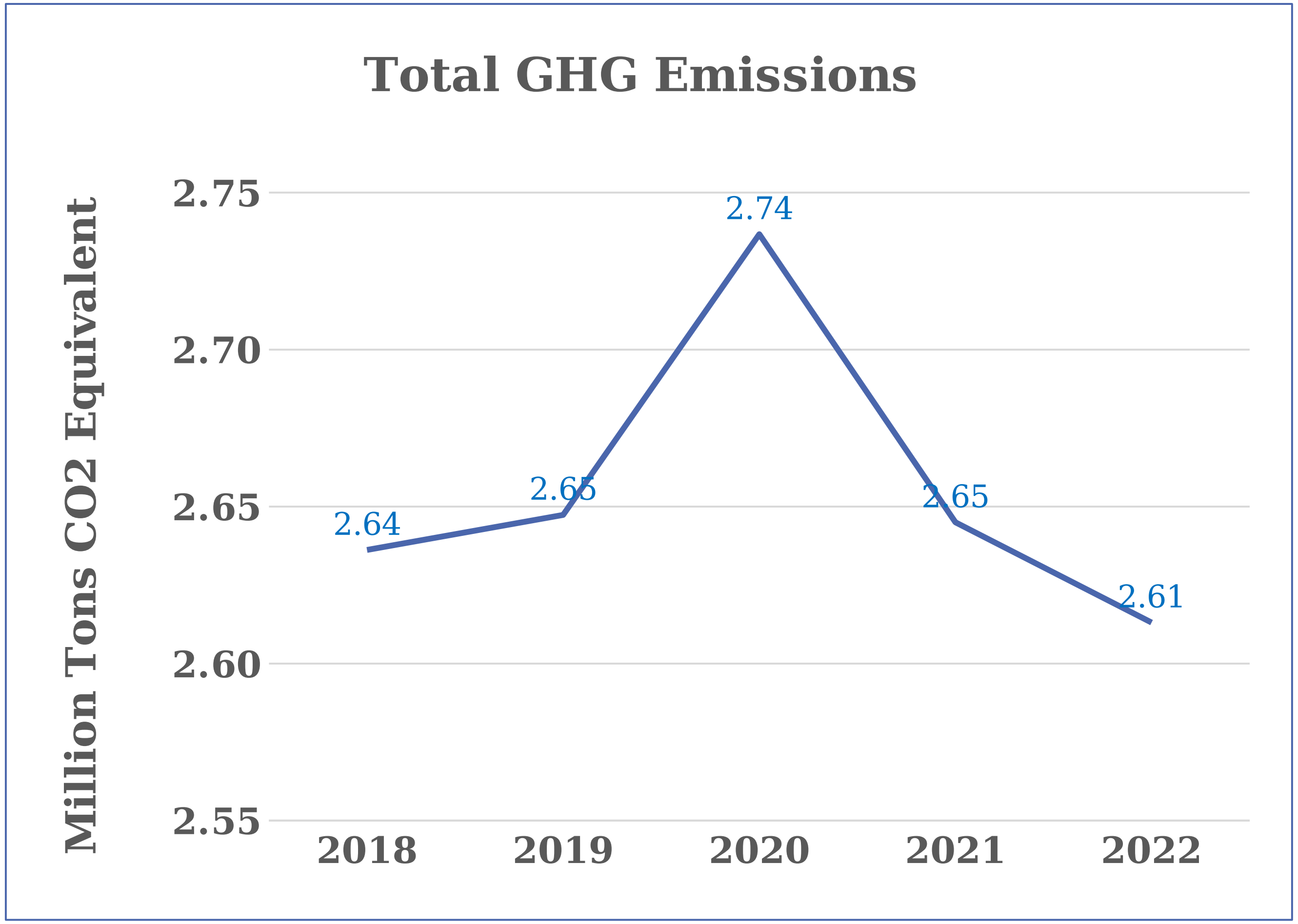
Environmental Expenditure

Over the past five years, we have invested USD 48.4 million in environmental programs and technologies. In 2022, this amounted to USD 9.9 million (a 13% increase on the previous year). Investments in impact prevention and environmental management made up approximately 82% of expenditure, with 18% allocated to treatment and disposal of waste.



Emissions and Air Quality

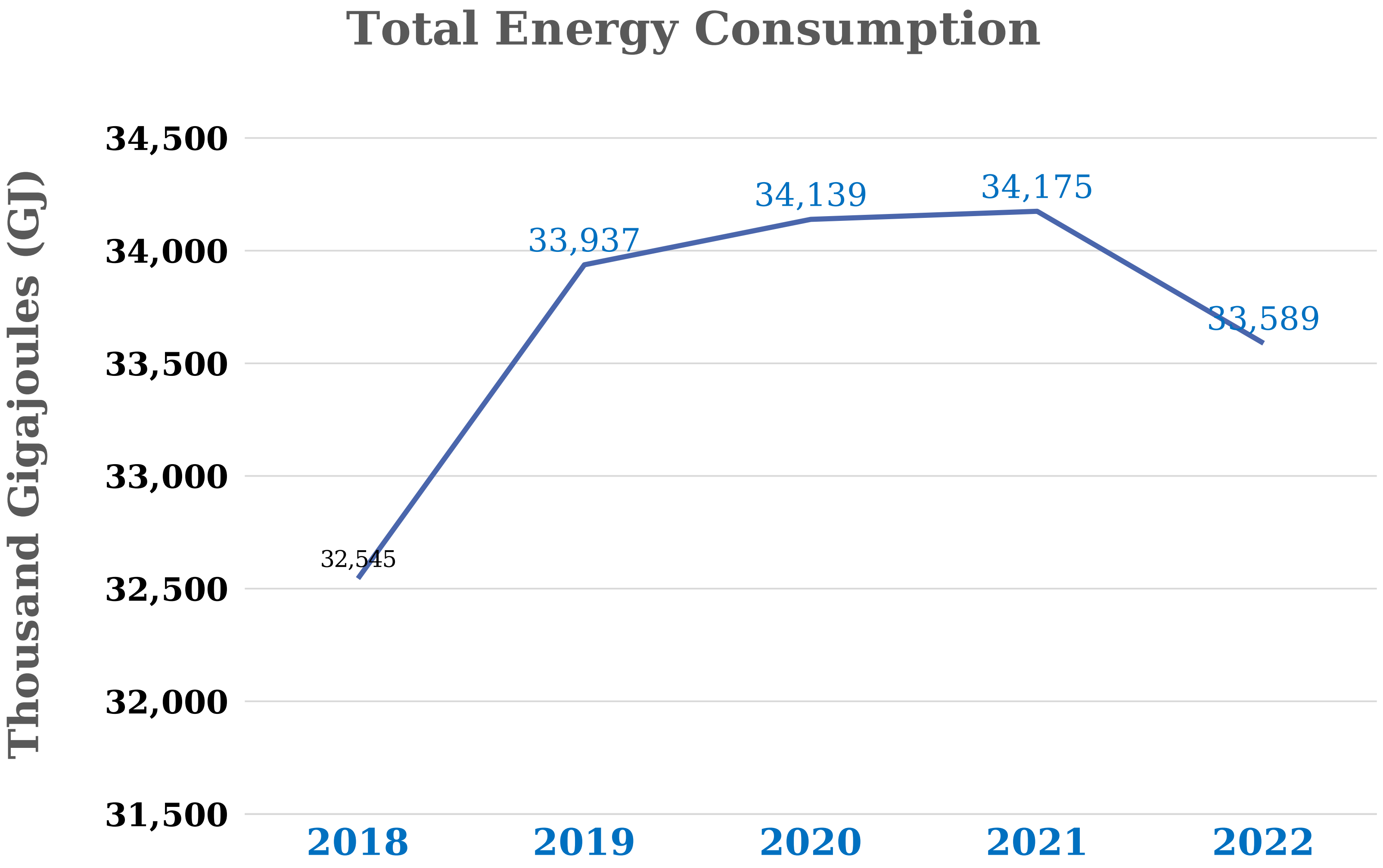




Managing greenhouse gas (GHG) emissions and other emissions to air is vital to our decarbonization roadmap and to maintaining clean, healthy air for our employees and communities

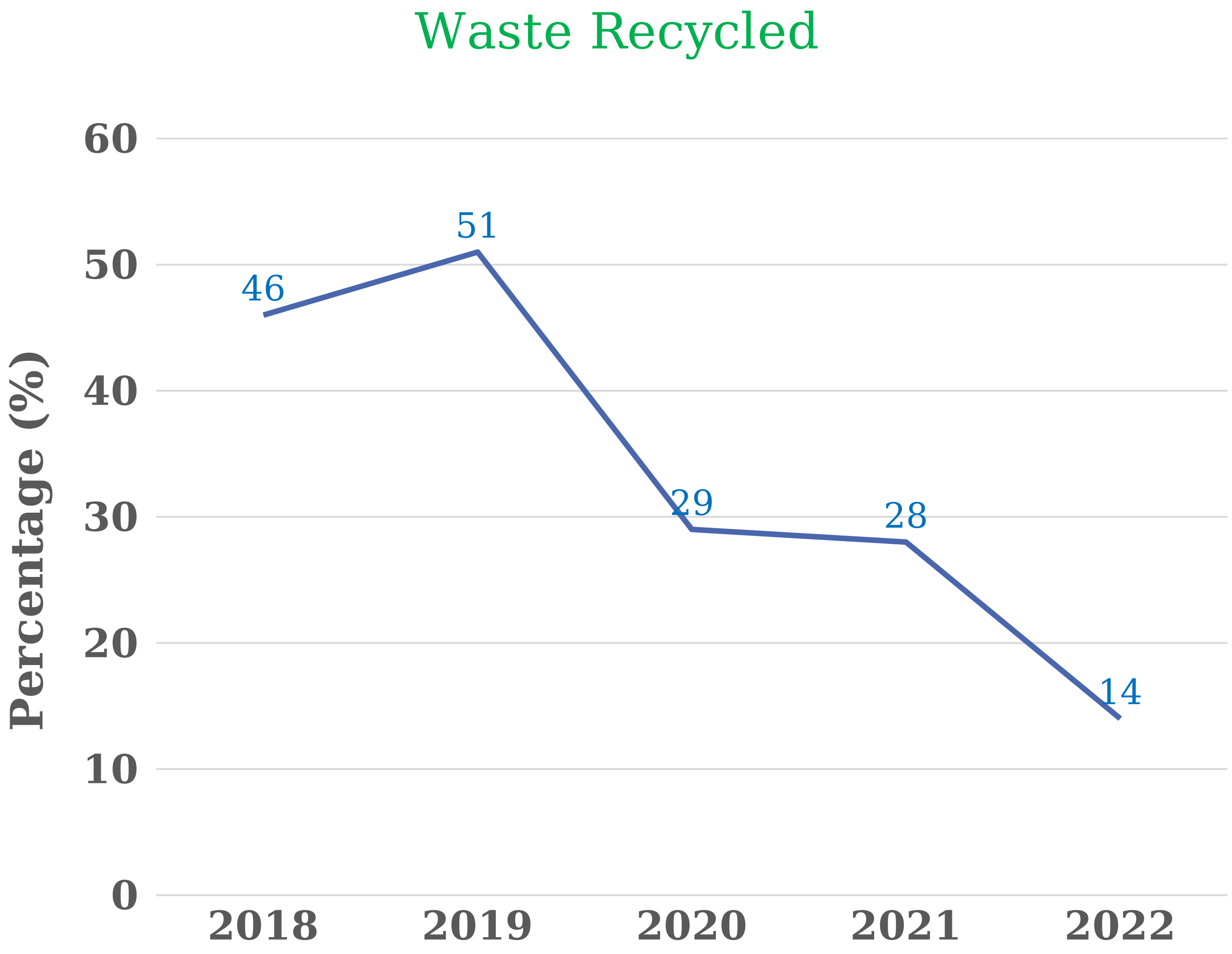
Energy Use and Efficiency

In 2022, we reduced total energy consumption by 1.7% compared to 2021, with most of our consumption in upstream operations. We increased electricity generated at our own plant upstream, thus reducing the requirement to import from the grid.



Waste Management

To reduce quantities of waste disposed into landfill, we identify opportunities and synergies with other industries so that the waste we generate is taken by another industry for reuse. We have recycling programs in place not only for our office waste but also for electronics and several of our non-hazardous industrial waste.

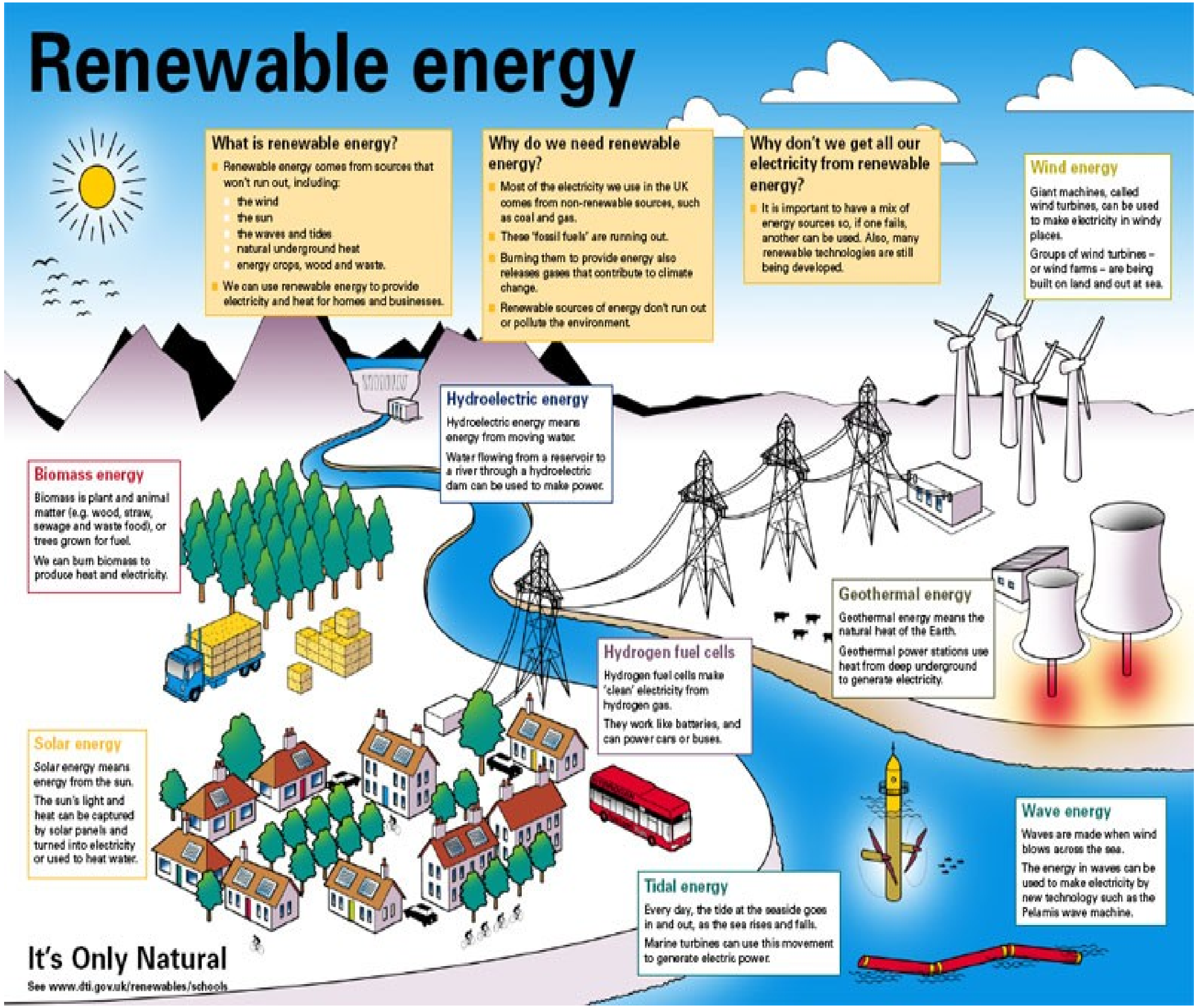


Energy Trends:
Renewables and Efficiency

The nature of renewable energies (RE)

Are they SUSTAINABLE ?

- **REs are renewed, no-finite, they can be replenished** during short or human lifetime spans.
- They are not free from environmental impacts.
- However, they do not use energy from prehistoric stocks, but from flows of energy happening around us.
- They release fewer carbon emissions
- Several of them are **intermittent in nature**, i.e., they cannot guarantee a constant supply of energy but only during certain periods of the day



Renewable energy

What is renewable energy?

- Renewable energy comes from sources that won't run out, including:
  - the wind
  - the sun
  - the waves and tides
  - natural underground heat
  - energy crops, wood and waste.
- We can use renewable energy to provide electricity and heat for homes and businesses.

Why do we need renewable energy?

- Most of the electricity we use in the UK comes from non-renewable sources, such as coal and gas.
- These 'fossil fuels' are running out.
- Burning them to provide energy also releases gases that contribute to climate change.
- Renewable sources of energy don't run out or pollute the environment.

Why don't we get all our electricity from renewable energy?

- It is important to have a mix of energy sources so, if one fails, another can be used. Also, many renewable technologies are still being developed.

Wind energy

Giant machines, called wind turbines, can be used to make electricity in windy places.

Groups of wind turbines – or wind farms – are being built on land and out at sea.

Hydroelectric energy

Hydroelectric energy means energy from moving water.

Water flowing from a reservoir to a river through a hydroelectric dam can be used to make power.

Biomass energy

Biomass is plant and animal matter (e.g. wood, straw, sewage and waste food), or trees grown for fuel.

We can burn biomass to produce heat and electricity.

Geothermal energy

Geothermal energy means the natural heat of the Earth.

Geothermal power stations use heat from deep underground to generate electricity.

Hydrogen fuel cells

Hydrogen fuel cells make 'clean' electricity from hydrogen gas.

They work like batteries, and can power cars or buses.

Solar energy

Solar energy means energy from the sun.

The sun's light and heat can be captured by solar panels and turned into electricity or used to heat water.

Tidal energy

Every day, the tide at the seaside goes in and out, as the sea rises and falls.

Marine turbines can use this movement to generate electric power.

Wave energy

Waves are made when wind blows across the sea.

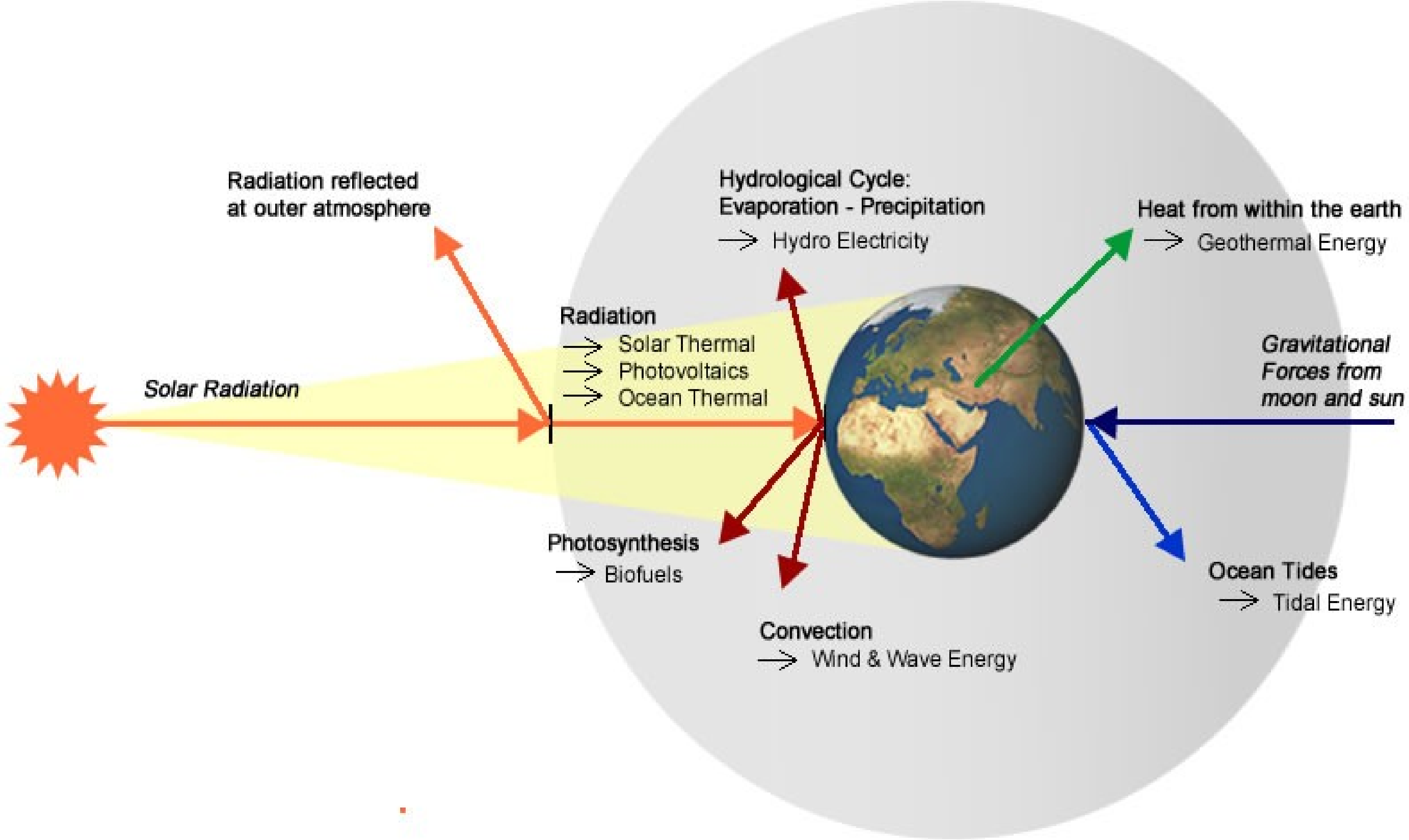
The energy in waves can be used to make electricity by new technology such as the Pelamis wave machine.

It's Only Natural

See www.dti.gov.uk/renewables/schools

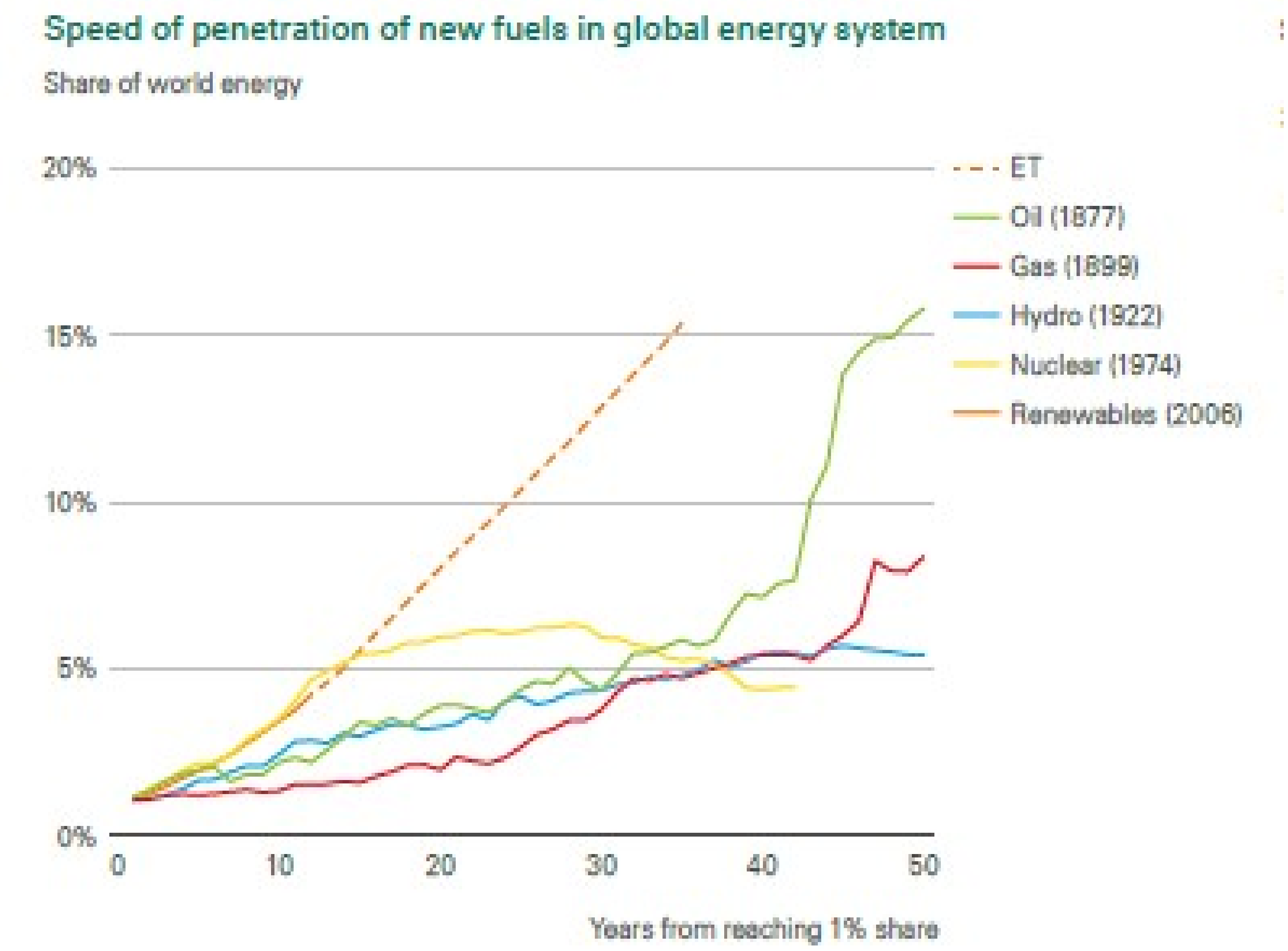
RE Sources

- The flows of energy allowing the operation of REs are the same that feed the Earth’s natural processes every day.
- There are **3 mains sources** of renewable energy:
  - **Solar energy** (interacting in different forms in the Earth)
  - **Gravitational forces**: the pull of other celestial forces near the Earth.
  - **Nuclear decay** and frictional forces inside the Earth.
- These sources interact, combine and structure the renewable energy resources we have and

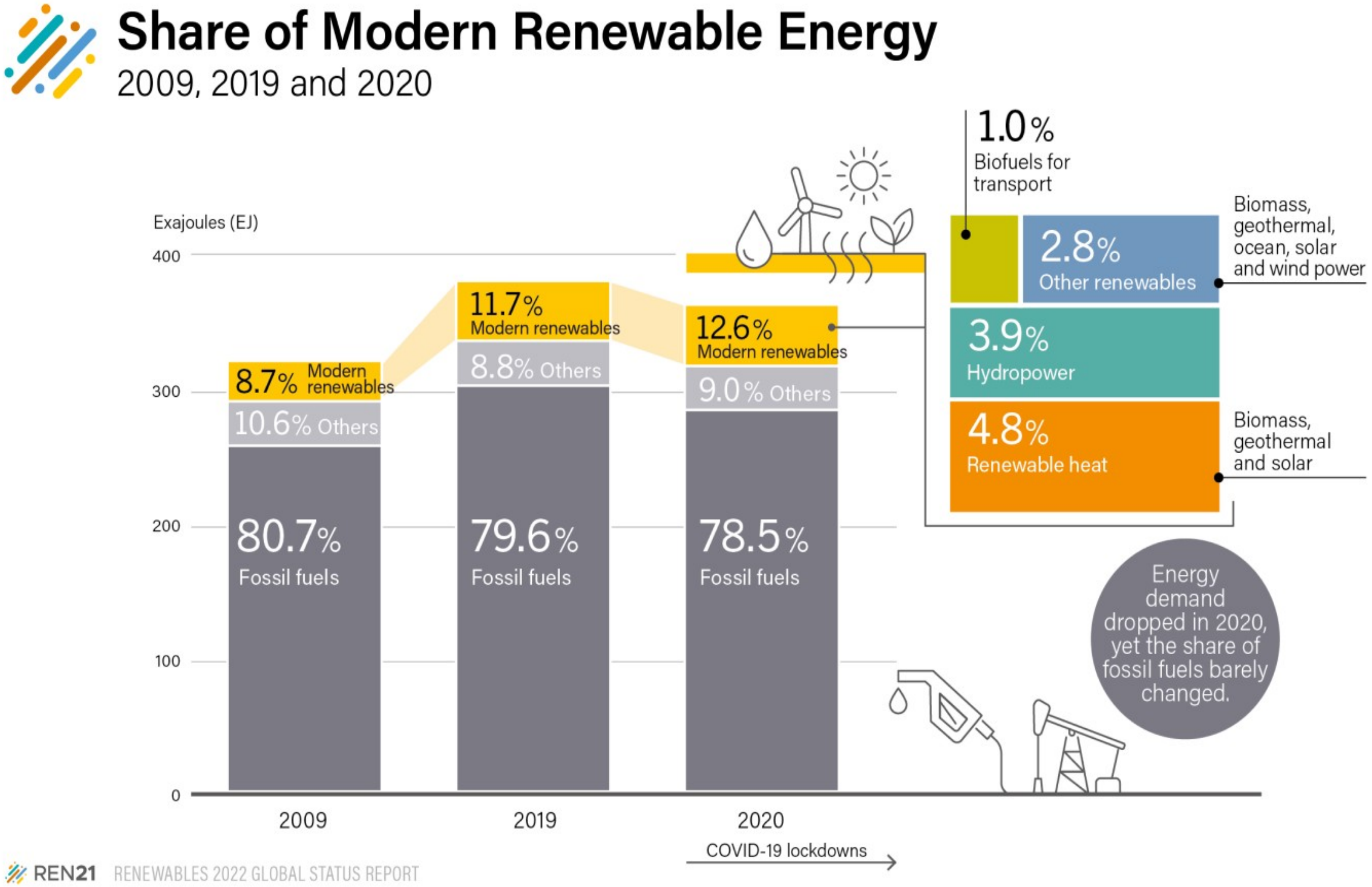

Radiation reflected
at outer atmosphere
Solar Radiation
Hydrological Cycle:
Evaporation - Precipitation
→ Hydro Electricity
Heat from within the earth
→ Geothermal Energy
Radiation
→ Solar Thermal
→ Photovoltaics
→ Ocean Thermal
Gravitational
Forces from
moon and sun
Photosynthesis
→ Biofuels
Ocean Tides
→ Tidal Energy
Convection
→ Wind & Wave Energy

Future projections and growth

- **In percentage terms, RE are growing remarkably fast.**
- They are growing faster than the historic development of other energy sources in the past.
- However, their **shares are still small when compared to fossil fuels.**
- When we compare to the timeframes we have set to phase out fossils fuels and decrease our carbon emissions, we still need to do more.



Shares of renewable energies (2020)



- **12% of the energy** consumed globally for heating, power, and transportation was **from renewable sources in 2020**.
- Nearly **60% of this 12% came from modern renewables** (i.e., biomass, geothermal, solar, hydro, wind, and biofuels) and the remainder from traditional biomass (used in residential heating and cooking in developing countries).

Renewable energies: final balance

Pros

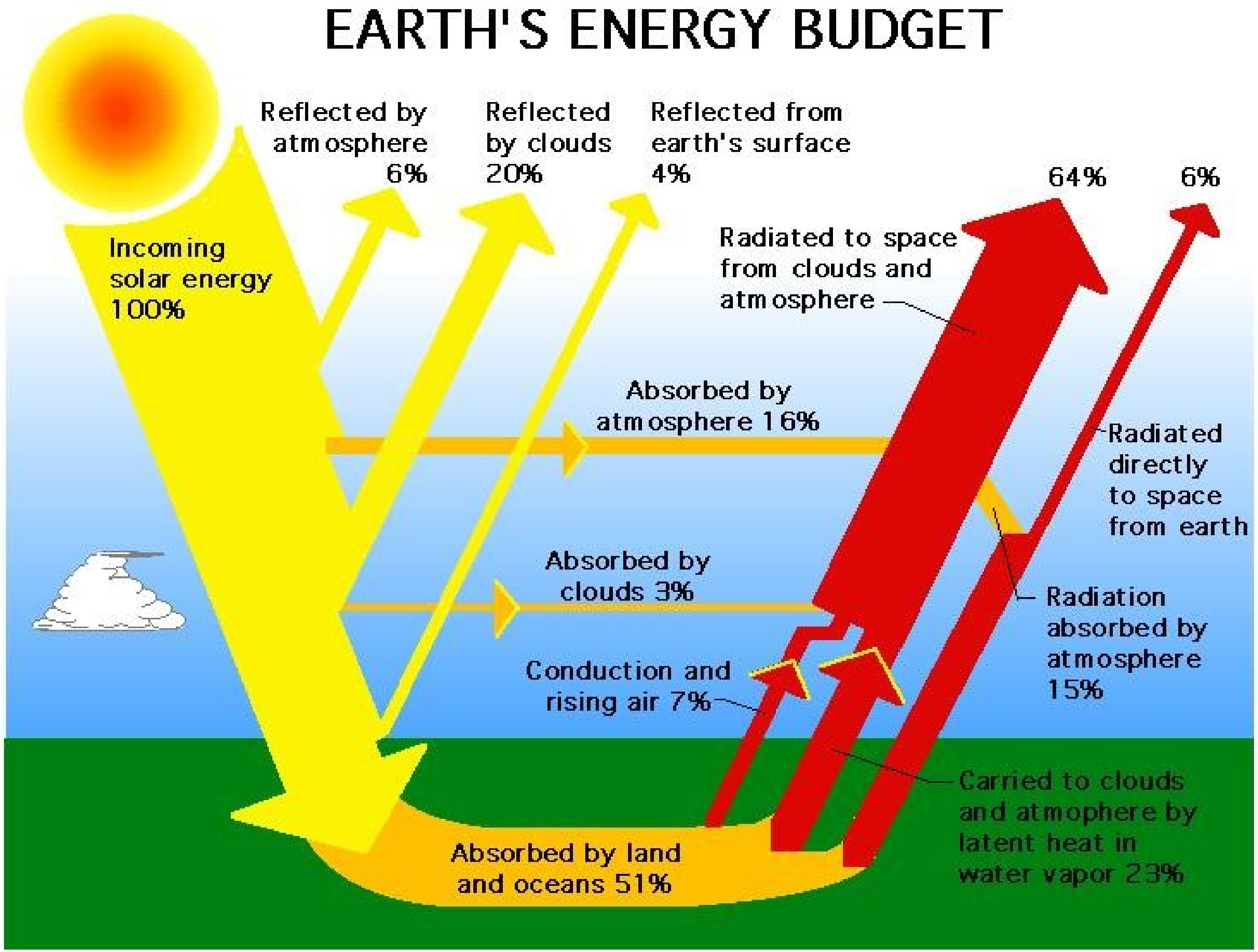
- Renewable energies are the future: they are mostly **carbon-free or carbon-neutral**, and definitely with minor carbon emissions than mineral fuels.
- They are **sustainable**, they are part of huge stocks and flows of energy which are **constantly regenerated**. They **do not harm nature**, altering it seriously.
- They are **growing cheaper** and in many cases, their **operation is close to free** because the energy flows from the environment are free.
- They have a **huge potential**, they are ubiquitous and have global reach.
- They **create jobs and new industrial-economic activities**

Cons

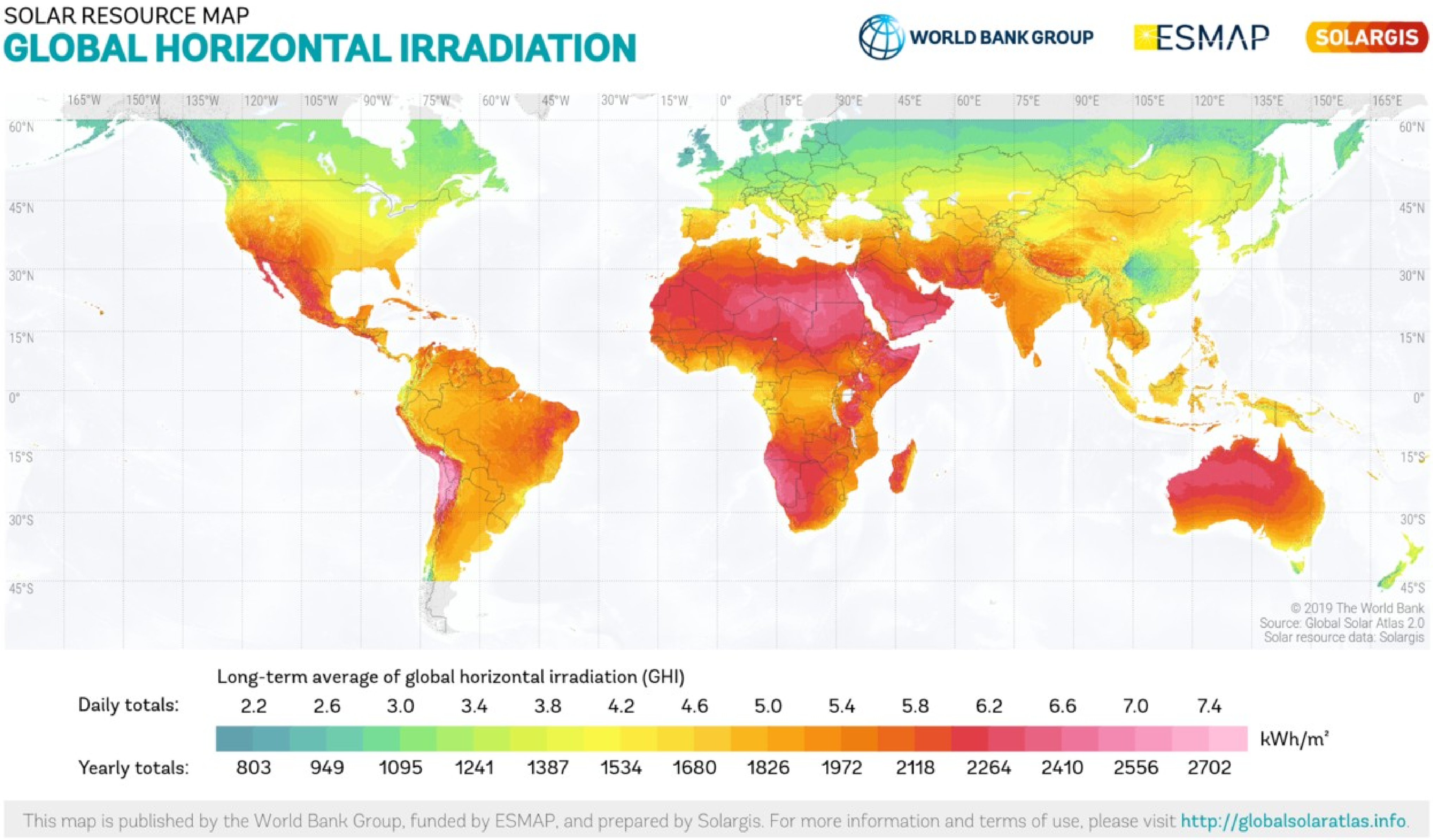
- There is still a **long way to make RE commercially attainable**. Also R&D should work a lot on the technological feasibility and potential of many of them.
- They are **not impact-free**. RE have different impacts, some of them difficult to accept, but we can work them out.
- **Installation/upfront costs could be very high** in some of them.
- Using RE is going to alter definitely our energy systems and power networks, needing a **change on the model of huge producer**, multiple consumers to multiple small consumer/producers (prosumers).
- Also, we would need to **work more on smart networks** capable of managing the exchanges of power among multiple players

Solar Energy Potential

- The Sun is a star **radiating energy all over the Solar system**
- It reaches the Earth atmosphere, radiating 1354 W/m2 or 429 BTU/ft2 hr)
- Depending on weather conditions, season and hour, it **reaches the Earth surface between 0 and 1050 W/m2**


EARTH'S ENERGY BUDGET
Incoming solar energy 100%
Reflected by atmosphere 6%
Reflected by clouds 20%
Reflected from earth's surface 4%
64%
6%
Radiated to space from clouds and atmosphere
Absorbed by atmosphere 16%
Radiated directly to space from earth
Absorbed by clouds 3%
Radiation absorbed by atmosphere 15%
Conduction and rising air 7%
Carried to clouds and atmophere by latent heat in water vapor 23%
Absorbed by land and oceans 51%

Challenges & Opportunities in Middle East



SOLAR RESOURCE MAP
GLOBAL HORIZONTAL IRRADIATION

WORLD BANK GROUP
ESMAP
SOLARGIS
165°W
150°W
135°W
120°W
105°W
90°W
75°W
60°W
45°W
30°W
15°W
0°
15°E
30°E
45°E
60°E
75°E
90°E
105°E
120°E
135°E
150°E
165°E
60°N
45°N
30°N
15°N
0°
15°S
30°S
45°S
Long-term average of global horizontal irradiation (GHI)
Daily totals: 2.2 2.6 3.0 3.4 3.8 4.2 4.6 5.0 5.4 5.8 6.2 6.6 7.0 7.4
kWh/m²
Yearly totals: 803 949 1095 1241 1387 1534 1680 1826 1972 2118 2264 2410 2556 2702

© 2019 The World Bank
Source: Global Solar Atlas 2.0
Solar resource data: Solargis

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Types of solar energy technologies

Solar photovoltaic systems

Simple photovoltaic systems

Concentrated photovoltaic systems

Solar thermal electric systems

Solar thermal

Concentrated solar power

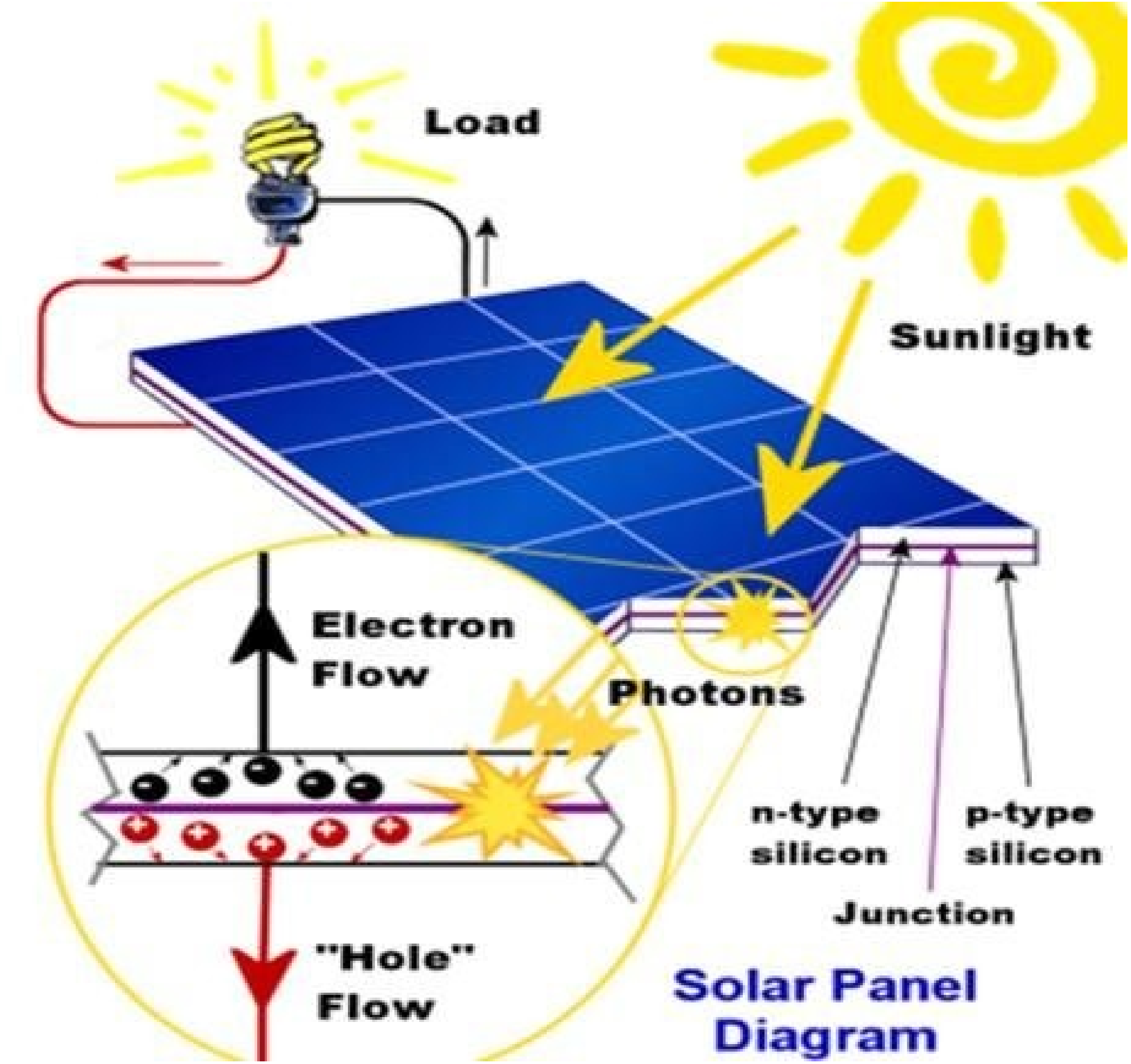
Photovoltaic systems make use of the **photoelectric effect**, the **radiation of solar energy in a surface to generate electricity**

Thermal systems try the **collect the Sun heat energy on the surface to heat fluids** and make **use of such energy as heat or power**

Solar photovoltaic systems (PV)

How do they work?

- Photovoltaic (PV) systems are based on the **transformation of infrared light into electric energy** (photoelectric effect).
- Incoming light is converted into electrons (-) and holes (+) by absorption of photons. Usually one photon makes the electron – hole pair.
- **PV systems must be made of materials which make easy the flow of electrons into one direction.**
- Complementary, PV systems should have holes flow in the opposite direction.
- **PY systems are made of semiconductor materials**


Load
Sunlight
Electron Flow
Photons
n-type silicon
p-type silicon
Junction
"Hole" Flow
Solar Panel Diagram

Solar photovoltaic systems

Simple or conventional PV

- **Simple PV systems are static panels** of PV.
- They are the classical panels **used on rooftops of houses and commercial premises.**
- They are also in some industrial applications and off-the-grid installations.
- **Their popularity comes from their versatility to install, operate and maintain**

Solar photovoltaic systems

Concentrated PV systems

- They **use the same photoelectric effect as with conventional PV systems.**
- However, unlike conventional PV, **concentrated PV (CPV) make use of concave lenses to concentrate the solar light.**
- **The lenses concentrate such light onto a small, highly efficient multi-junction (MJ) solar cells.**
- Often they use a solar tracker and cooling system to enhance the efficiency.
- CPV is starting its way to be commercially competitive, for instance in the US, China, Europe.
- **It is one of the most efficient solar technologies, and has a bright future**

Solar Thermal Electric Systems

Solar Thermal

- Solar Domestic Hot Water (SDHW): Flat Panels.
- SDHW: Thermo syphon
- SDHW: Evacuated Tube Collectors
- Solar air panels
- Trombe Wall
- Solar Chimney

Solar thermal systems use the thermal energy of the Sun to hot other fluids or generate electricity.

Concentrated Solar Thermal

They work the same as the normal solar thermal systems, but make us of configurations to **concentrate the sun beams and transfer the heat to the fluid exchanger.**

Solar technologies: Pros and cons

Advantages

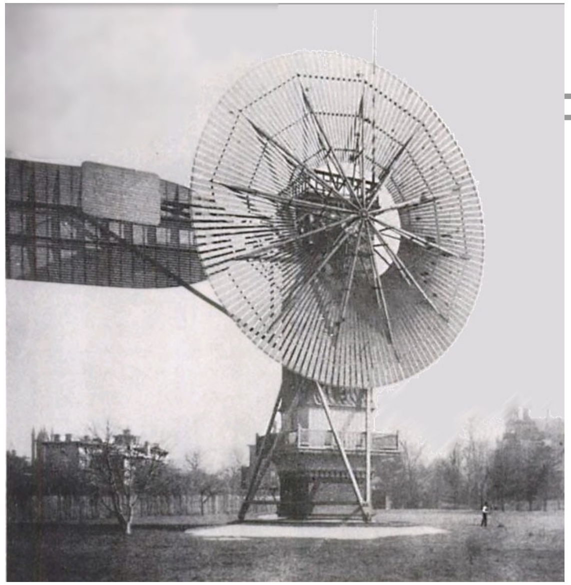
- **Renewable energy,** with very few carbon emissions
- Could help to **reduce the electricity bills** and even **sell power to the grid.**
- **Adaptable and versatile for small installations and off-the-grid / isolated areas**.
- **Low maintenance costs**, at least in the most mature and domestic technologies.
- Continuous technological development, reducing costs

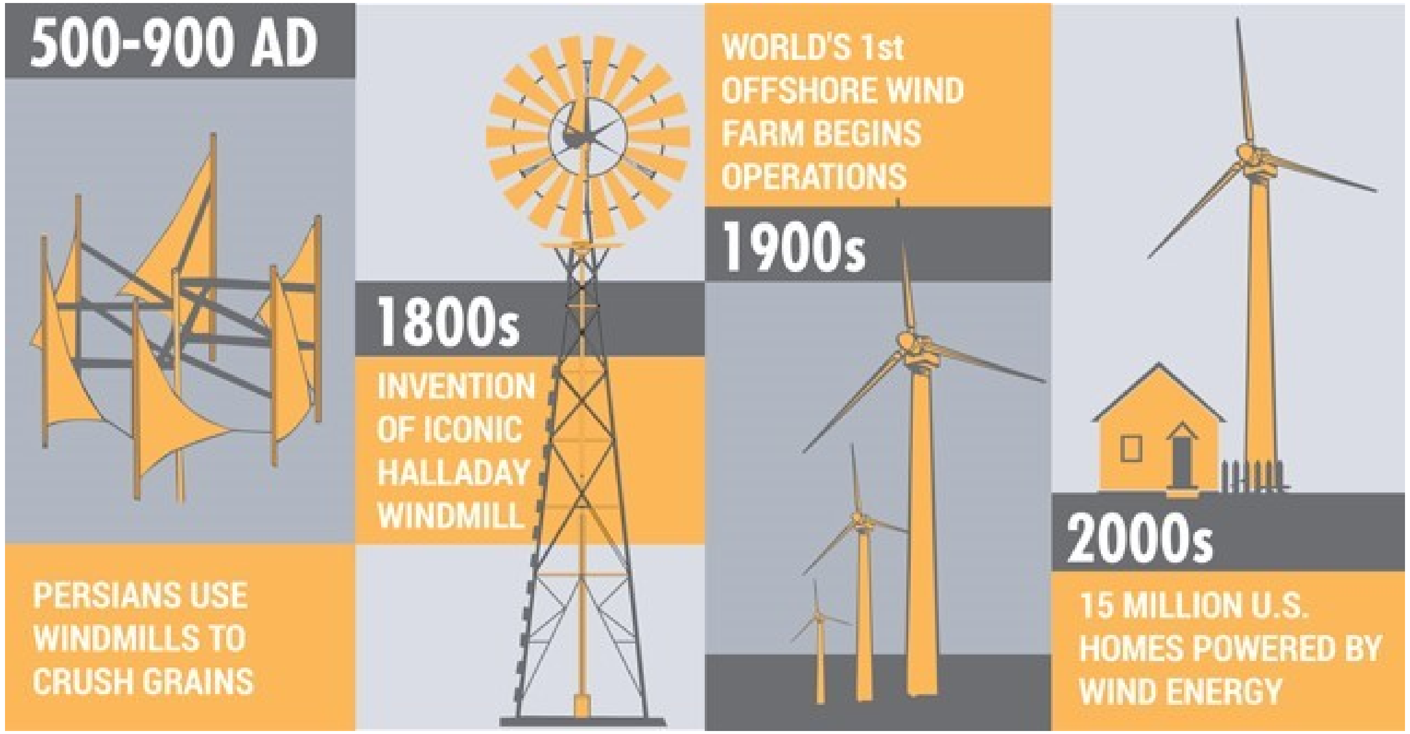
Disadvantages

- **Procurement and installation costs could still be high**.
- It **depends highly on favorable weather conditions and season**.
- There are still **problems on the energy storage side.**
- Could **use a considerable space** (the industrial configurations)
- **Associated with other types of pollution, on the demand of special manufacturing materials for PV.**

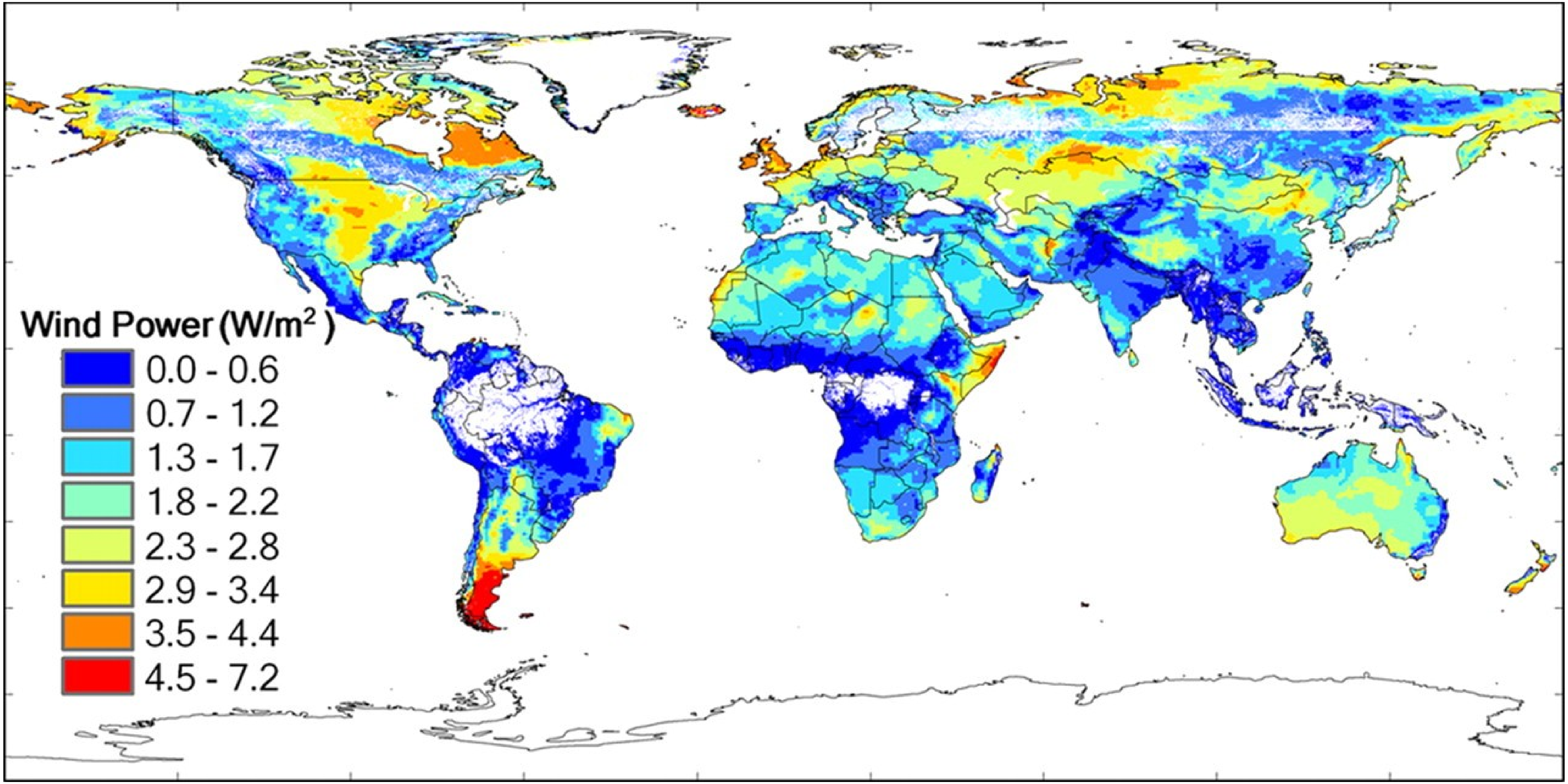
Wind power

- Wind energy is **one of the main renewable energies and used since ancient times.**
- Wind was used as far as to **power sail ships and windmills for farmers in Europe in past centuries.**
- Wind comes from the uneven heating of the land and sea surfaces (i.e. wind energy stems from solar energy).
- **Wind energy is one of the main potential renewable energies**; by the use of wind turbines and mills, it harvests free energy.
- **The total amount of economically extractable power available from the wind is considerably more than present human power use from all sources** (source https://claverton-energy.com/how-much-wind-energy-is-there-brian-hurley-wind-site-evaluation-ltd.html)

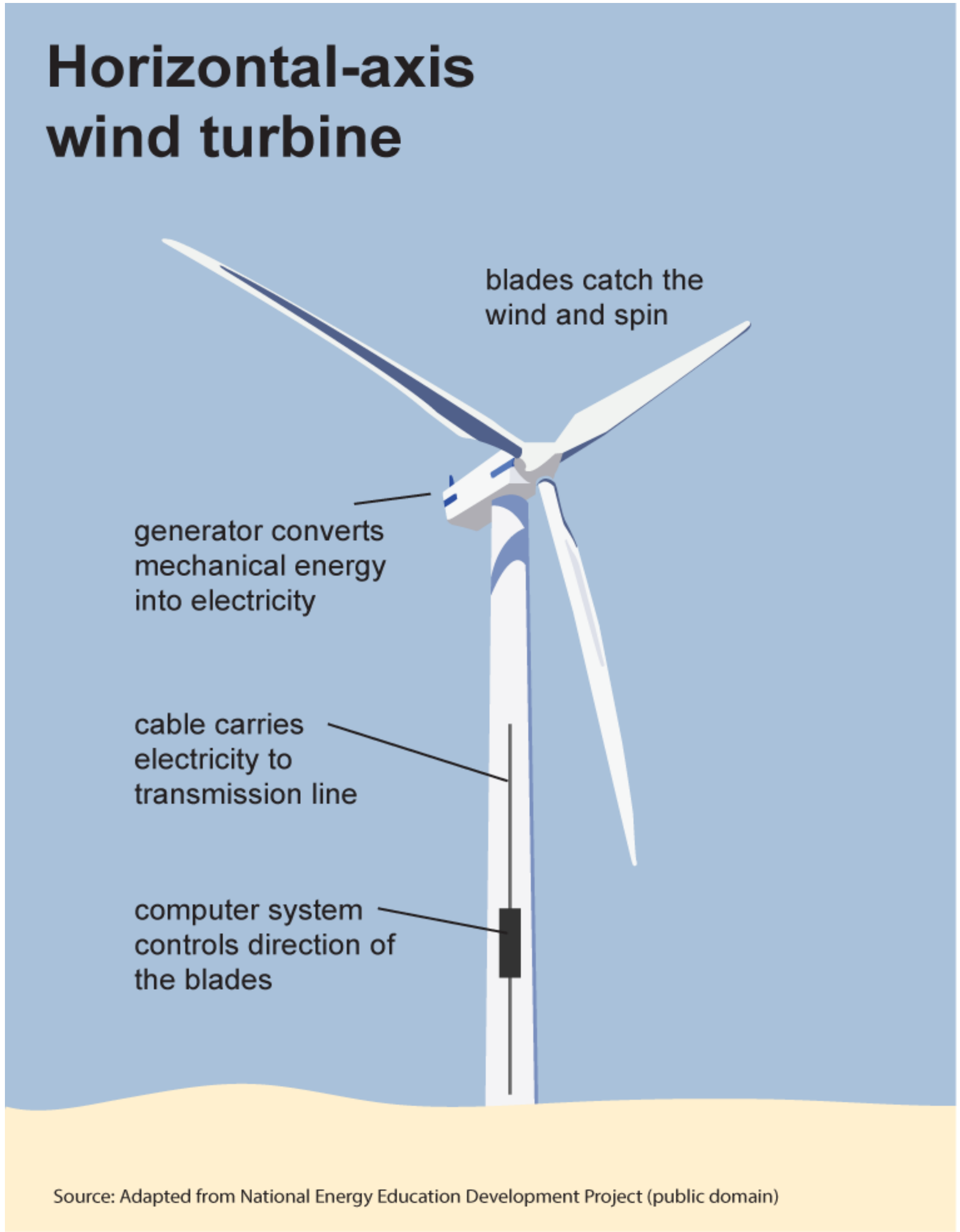



500-900 AD
PERSIANS USE WINDMILLS TO CRUSH GRAINS
1800s
INVENTION OF ICONIC HALLADAY WINDMILL
WORLD'S 1st OFFSHORE WIND FARM BEGINS OPERATIONS
1900s
2000s
15 MILLION U.S. HOMES POWERED BY WIND ENERGY

Wind power potential


Wind Power (W/m²)
0.0 - 0.6
0.7 - 1.2
1.3 - 1.7
1.8 - 2.2
2.3 - 2.8
2.9 - 3.4
3.5 - 4.4
4.5 - 7.2

Wind turbines and wind farms


Horizontal-axis wind turbine
blades catch the wind and spin
generator converts mechanical energy into electricity
cable carries electricity to transmission line
computer system controls direction of the blades

Source: Adapted from National Energy Education Development Project (public domain)

- **Wind turbines are used to harness wind mechanical power by rotating an electric generator.**
- There are 2 main types of wind turbines: a) horizontal axis b) vertical axis. Horizontal are the most used.
- Almost all large wind turbines have the same design — a horizontal axis wind turbine having an upwind rotor with 3 blades, attached to a nacelle on top of a tall tubular tower
- Usually **wind turbines are installed in large clusters, called wind farms, either onshore and offshore.**
- **Wind farms are all connected to gather the generated electricity and dispatch to the power transmission network.**
- Wind potential depends on the location and increases with altitude, i.e. **wind speed is higher at higher altitudes and locations.**
- A large wind farm may consist of several hundred individual wind turbines distributed over an extended area

Wind power on Land & at Sea

Onshore

- **The largest wind farms are located onshore**.
- They are usually located on coastal areas, top of hills, plains and even agricultural fields.
- An example is the **Gansu wind farm in China, the largest in the world with 7965 MW.**
- There are many large wind farms in the US.

Offshore

- Even though it is **more difficult and expensive**, there are large offshore wind farms.
- Offshore wind farms use unlock the large potential of marine areas, where **wind runs free for kilometers at faster speeds**.
- In 2012, **1,662 turbines at 55 offshore wind farms in 10 European countries produced 18 TWh, enough to power almost five million households.**

Wind power: Pros and cons

Advantages

- **A renewable and sustainable source of energy**, with not carbon emissions.
- Depending on the potential, location, installation, **wind power is free and with a large potential**.
- Wind turbines could be installed in ranches, farmlands and **without major disturbances on the land activities.**
- Small wind turbines (vertical axis) can even be installed next to roads, or urban settings to provide small amounts of power.
- **Wind power creates jobs.**

Disadvantages

- It is **intermittent in nature, it cannot provide power all the time**, at all hours and seasons.
- One should know the **best locations** to install the turbines and get the most of power (something difficult).
- Noise and aesthetic issues: Not many people like the look of wind farms near their houses or towns. **Wind turbines may be heard hundreds of meters away from their location.**
- **Threat to wildlife**: many windmills have been reported to kill birds, bats, etc.
- **Cost of land:** the land used for wind farms could get more profitable uses.

Hydropower energy

Definition and types

- Hydropower energy is **one of the most used renewable energies.**
- It was greatly **developed in the Industrial Revolution** and allowed the electrification processes in many parts of the world.
- **It uses the water potential and flow energy to produce electricity.**
- 3 types of Hydropower installations
  - ☐ Impoundment hydropower
  - ☐ Diversion or run-of-the-river
  - ☐ Pumped storage hydropower

Hydropower

Advantages

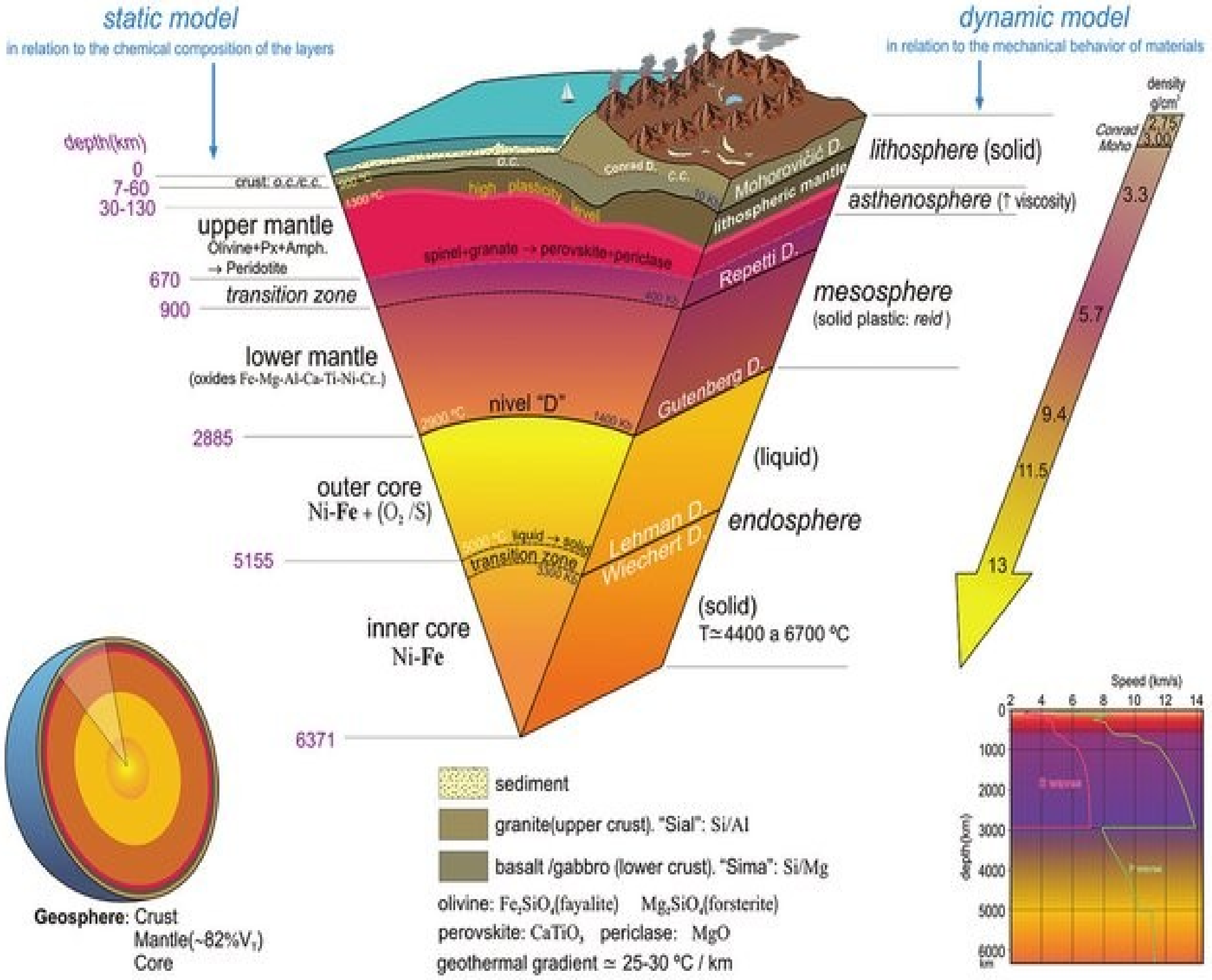
- It is a **well known source of energy** with a mature developed technology.
- It is a **continuous source of energy**, reliable in terms of time and easily complemented by other sources if needed.
- Besides the construction stage, there are no carbon emissions.
- It is **available when needed**, you just need to open the water flow to the turbines and direct the power where needed.
- The water impoundments or reservoirs created behind the dams could be used for fishing, recreational, swimming or other purposes.
- It is also useful as a mean for flow control and water supply.

Disadvantages

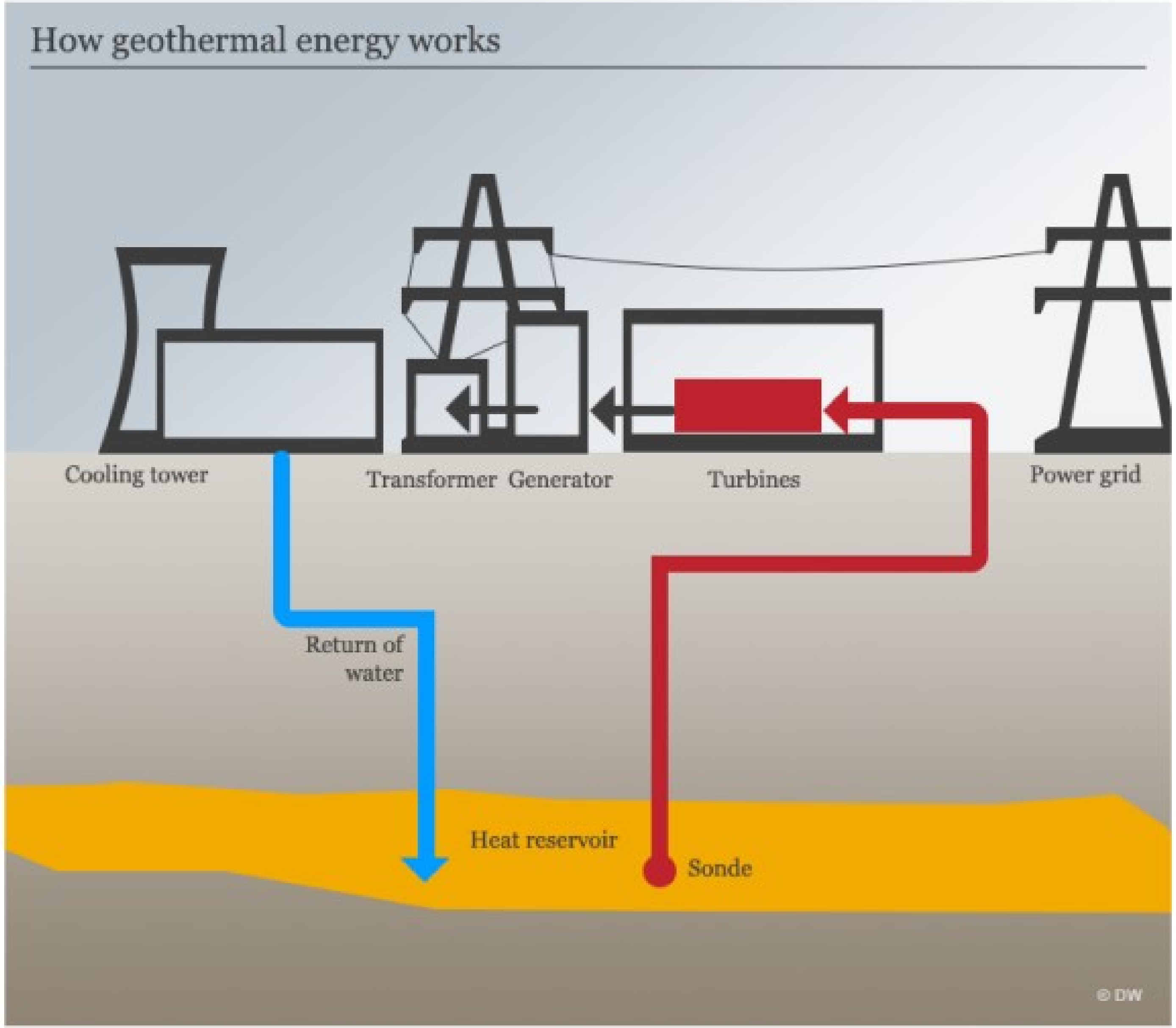
- There is **not too much potential left**, the best hydropower potential places have already been used.
- **Dams disturb the normal course of rivers** and associated habitats.
- **Fishes / water species and habitats are disturbed by the dams as they are not free migrate as before**.
- The use of land is altered by the water impoundment, which could have agricultural, cultural and other values.
- **Hydropower is seriously affected by droughts.**
- Sediments and minerals dragged downstream are interrupted, **impacting soils fertility**.

Geothermal Energy

- Geothermal energy is **thermal energy generated and stored below the Earth’s crust.**
- It is originated 5-10% from the old processes when Earth was created thousand of million of years ago.
- The rest comes from radioactive decay of nuclear elements such as uranium and plutonium.
- **Earth is composed of several layers**, but in general we have a) the **core**, b) the **mantle**, c) the **crust**.
- **The Earth irradiates heat from the core, which is around 5500 ºC.**
- The heat reaches the mantle.
- **Constant geological processes release part of this thermal energy in volcanic and plate-boundaries areas.**
- **Heat flows through the crust of the earth at a rate of 0.65W/m2 under the continents and 0.101W/m2 through the ocean floor**. The resulting thermal temperature gradients range from 25o and 30o / km.


static model
in relation to the chemical composition of the layers
depth(km)
0
7-60
30-130
670
900
2885
5155
6371
crust: o.c./c.c.
upper mantle
Olivine+Px+Amph.
→ Peridotite
transition zone
lower mantle
(oxides Fe-Mg-Al-Ca-Ti-Ni-Cr.)
nivel "D"
outer core
Ni-Fe + (O₂ /S)
liquid → solid
transition zone
inner core
Ni-Fe
o.c.
Conrad D.
c.c.
high plasticity level
spinel+granate → perovskite+periclase
Mohorovičić D.
lithospheric mantle
Repetti D.
Gutenberg D.
Lehman D.
Wiechert D.
dynamic model
in relation to the mechanical behavior of materials
lithosphere (solid)
asthenosphere (↑ viscosity)
mesosphere
(solid plastic: reid)
(liquid)
endosphere
(solid)
T≃4400 a 6700 °C
density g/cm³
Conrad
Moho
2.75
3.00
3.3
5.7
9.4
11.5
13
Speed (km/s)
2 4 6 8 10 12 14
0 1000 2000 3000 4000 5000 6000 km
depth (km)
Geosphere: Crust
Mantle(~82%V₁)
Core
sediment
granite(upper crust). "Sial": Si/Al
basalt /gabbro (lower crust). "Sima": Si/Mg
olivine: Fe₂SiO₄(fayalite) Mg₂SiO₄(forsterite)
perovskite: CaTiO₃ periclase: MgO
geothermal gradient ≃ 25-30 °C / km

Geothermal Energy


How geothermal energy works
Cooling tower
Transformer
Generator
Turbines
Power grid
Return of water
Heat reservoir
Sonde
© DW

- **Geothermal systems need a hot formation source.**
- From there we can get fluids or **pump down fluids through wells to the geological formations to extract the heat.**
- **The fluids sweep across the hot formations and return to surface to the turbines, which are rotated.**
- **The turbines make work the generators and we have electricity.**
- **Finally, the spent fluid is cool down and**

Hydrothermal systems

- They are the **most commercial geothermal system.**
- Frequently **located in or near zones of recent volcanism** and tectonism.
- **Water or steam in hydrothermal systems is usually of meteoric origin, typically located at depths of 1-4km at temperatures of 350C.**
- Water falls as rain or snow, percolates downward through sediments or fissures until it comes to a heat source. There it is heated rises toward the surface where it usually appears as geysers, hot springs, fumaroles.

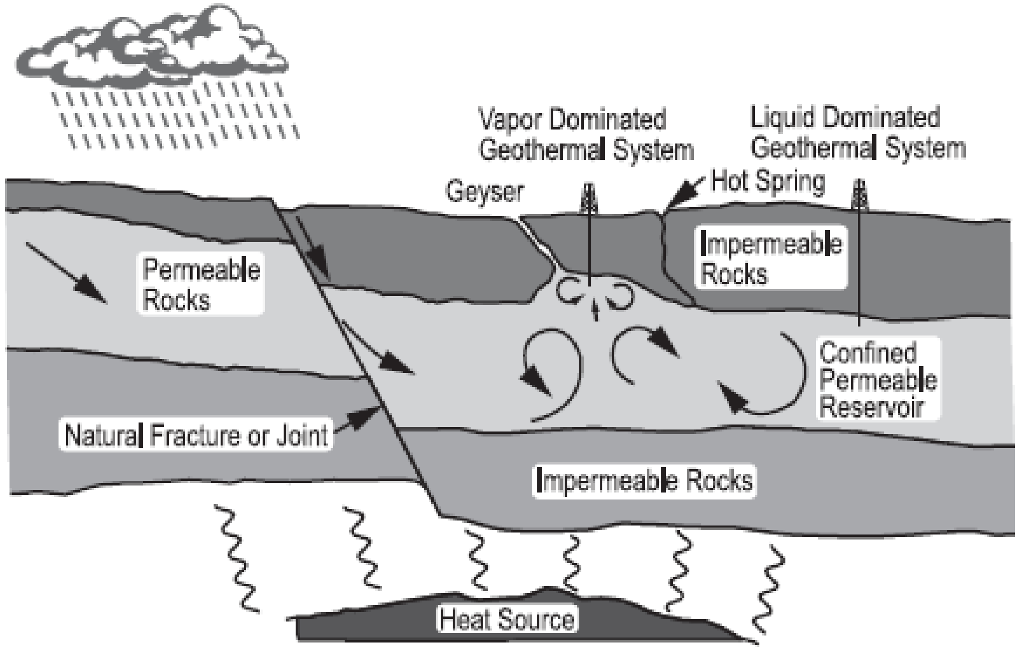
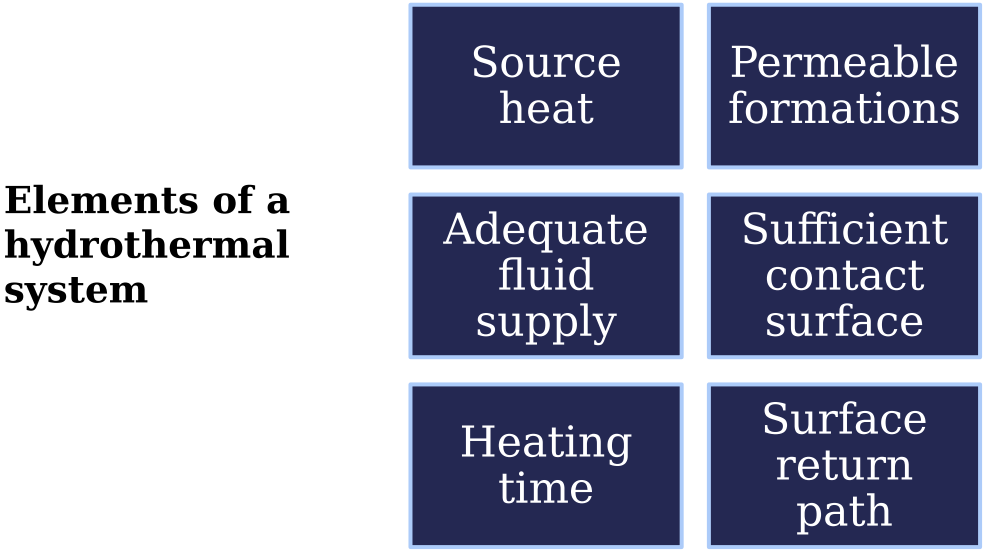

Vapor Dominated Geothermal System
Liquid Dominated Geothermal System
Geyser
Hot Spring
Permeable Rocks
Impermeable Rocks
Confined Permeable Reservoir
Natural Fracture or Joint
Impermeable Rocks
Heat Source

Figure 11.2
Typical features of a natural hydrothermal geothermal reservoir system. Adapted from Mock, Tester, and Wright (1997). Reprinted with permission of *Annual Review of Energy and the Environment*.



Elements of a hydrothermal system

Source heat

Permeable formations

Adequate fluid supply

Sufficient contact surface

Heating time

Surface return path

Geothermal: Pros and Cons

Advantages

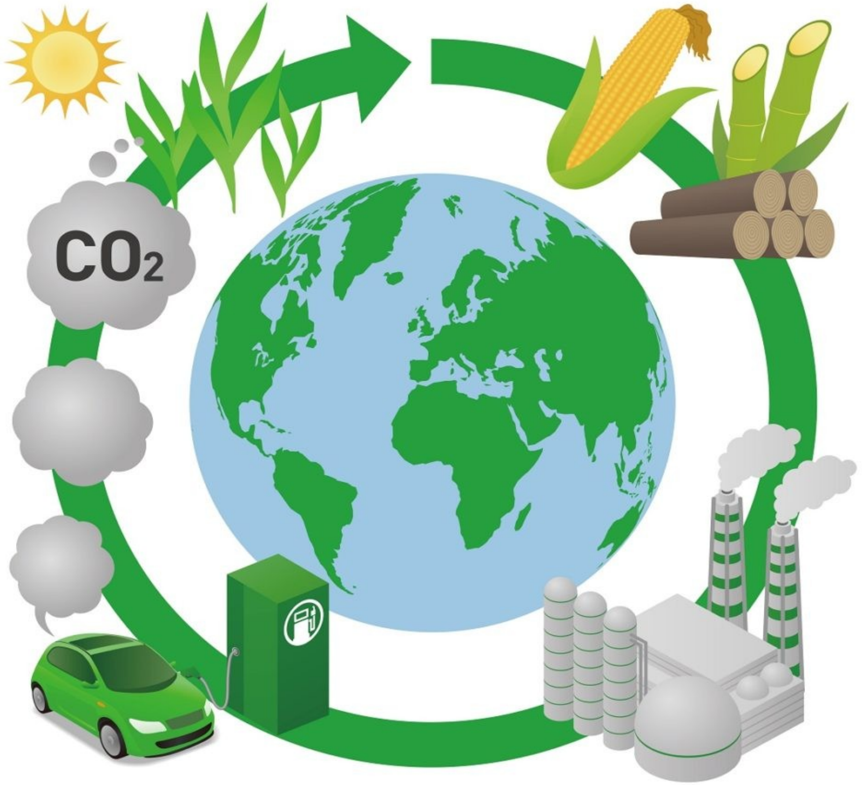
- Almost **no combustion, so environmentally friendly.**
- **Efficient** (300- 500% compared to 90% of the best furnaces)
- **Suitable for the smallest of houses to the largest commercial spaces**.
- It is **not fluctuating by the weather, season, solar activity.**
- **Most facilities underground, so minimal landscape disturbance.**
- It can make use of petroleum technology and abandoned oil and gas wells.
- Provides either base load or peak power energy output.
- Technology improvement continues (for instance in fracking underground formations)
- **It is basically inexhaustible**

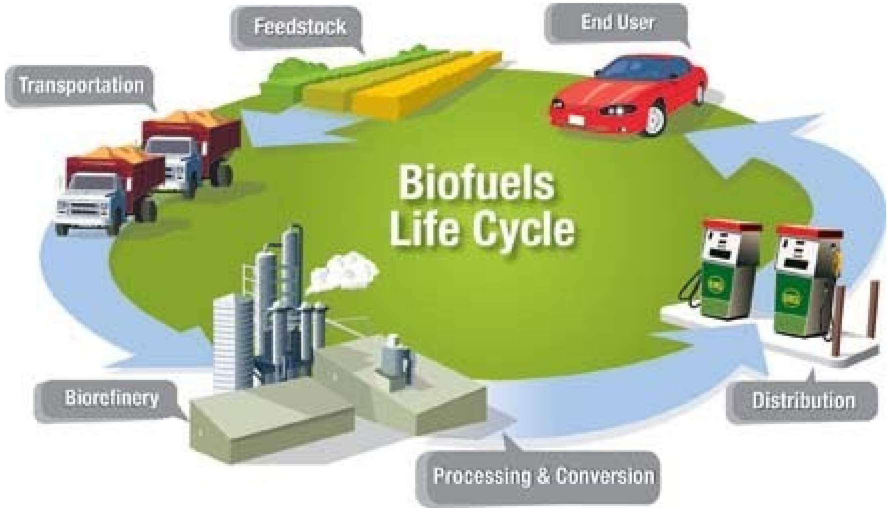
Disadvantages

- **High upfront costs with implementing geothermal energy.** ($10,000-$20,000)
- **More suitable for new home** builds as retrofitting involves large scale excavation.
- **Requires large quantities of water** if we plan to pump down water in the wells.
- Discharge into the Earth could include sulfur dioxide and silica (well pumps).
- **Electricity is still needed to operate heat pumps.**
- **Damage to underground loops (tree roots, rodents, etc.)** can be difficult and costly to repair.
- **For hydrothermal systems, not many places with available potential**

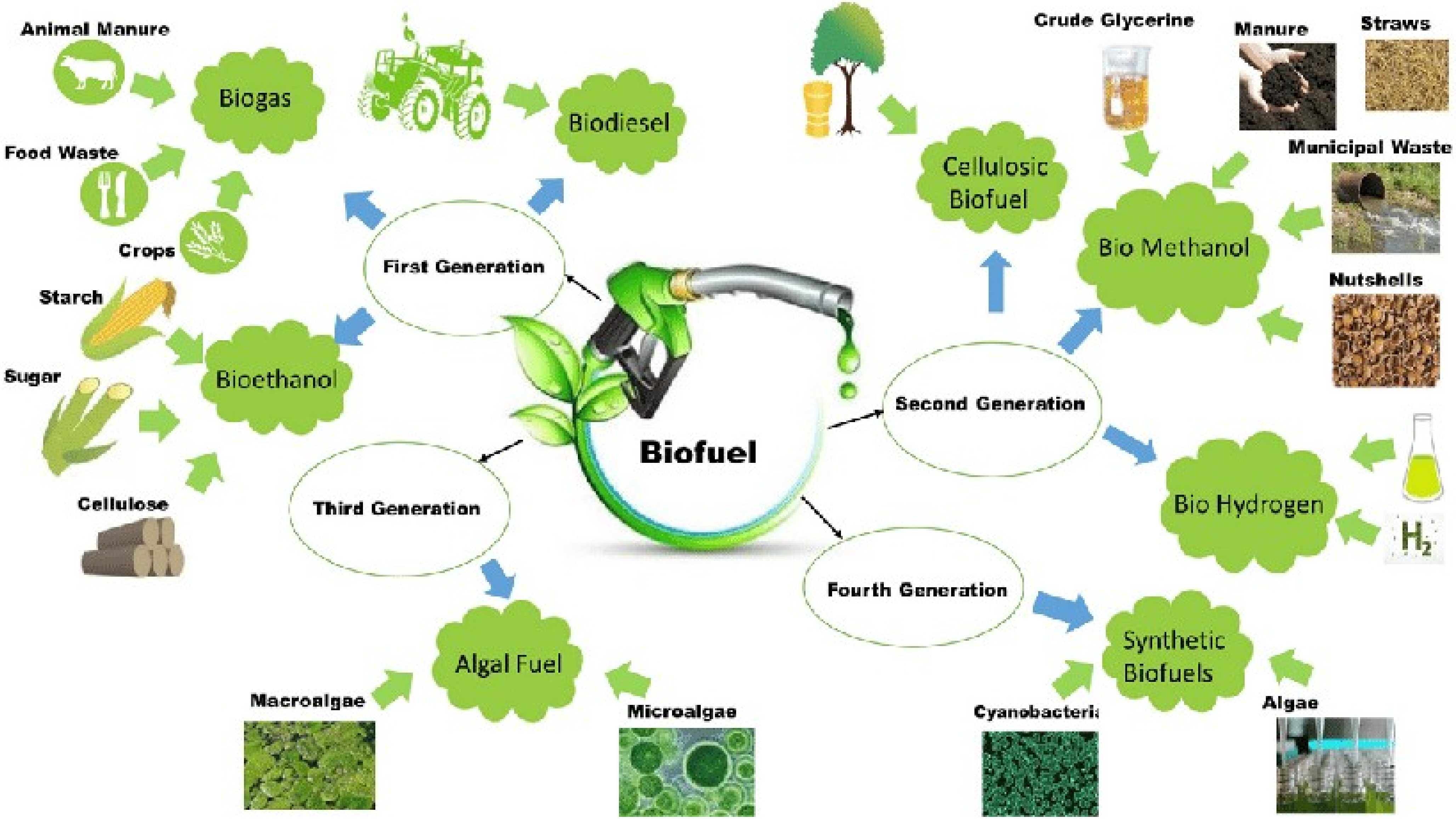
Biofuels

- **Biofuels are fuels made of contemporary processes from biomass** (unlike fossil fuels).
- The term **biofuel is usually reserved for liquid or gaseous substances** used as fuel for transportation.
- Biofuels **can be used as pure fuels in engines**, but they are mostly mixed with hydrocarbon fuels.
- Biofuels **feed stocks include plants and different types of wastes**. They help with carbon fixation and carbon sequestering.
- **The most used biofuels are bioethanol and biodiesel.**

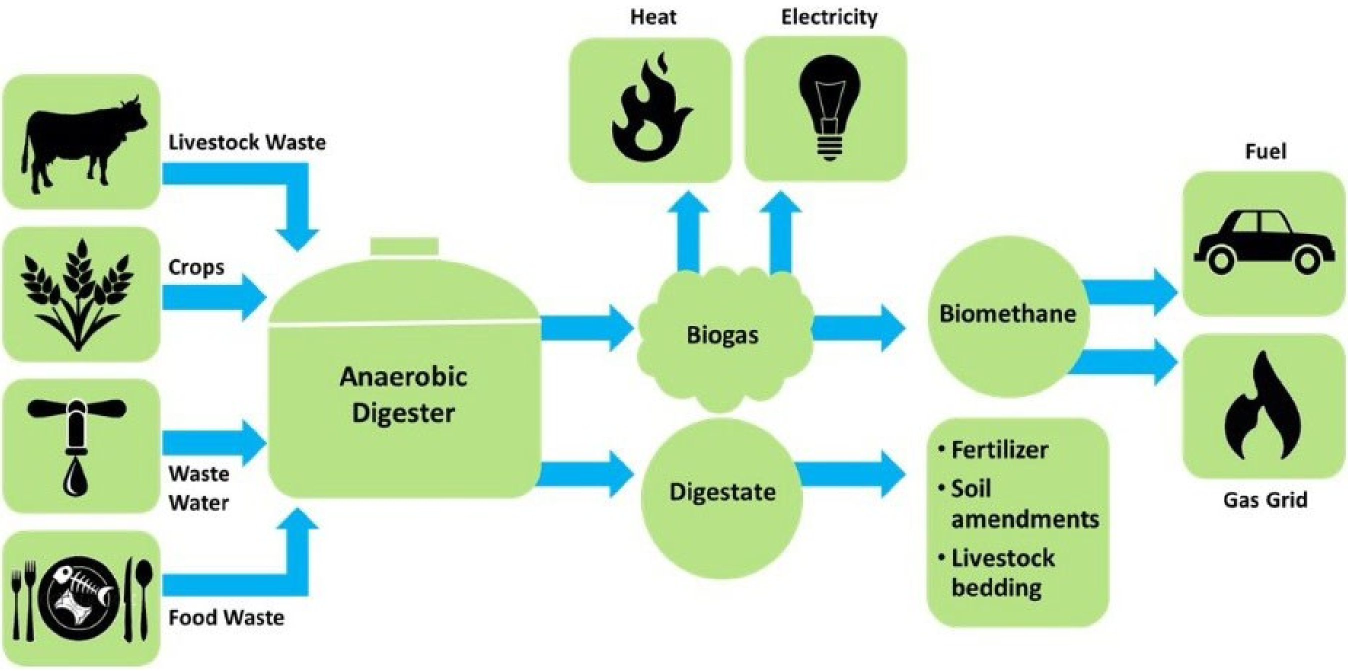


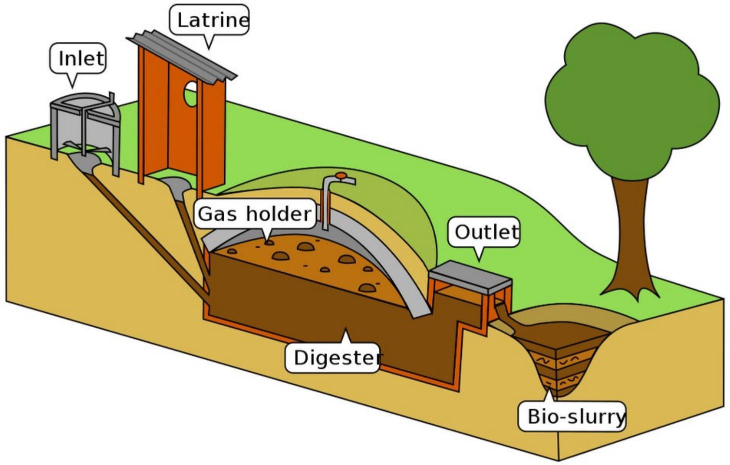

Feedstock
End User
Transportation
Biofuels Life Cycle
Biorefinery
Distribution
Processing & Conversion

Different types of biofuels


Animal Manure
Biogas
Biodiesel
Food Waste
Crops
Starch
Sugar
Bioethanol
Cellulose
First Generation
Third Generation
Biofuel
Algal Fuel
Macroalgae
Microalgae
Cellulosic Biofuel
Crude Glycerine
Manure
Straws
Municipal Waste
Bio Methanol
Nutshells
Second Generation
Bio Hydrogen
H_2
Fourth Generation
Synthetic Biofuels
Cyanobacteri
Algae

Biogas


Heat
Electricity
Livestock Waste
Crops
Waste Water
Food Waste
Anaerobic Digester
Biogas
Digestate
Biomethane
Fuel
Gas Grid
• Fertilizer
• Soil amendments
• Livestock bedding


Latrine
Inlet
Gas holder
Outlet
Digester
Bio-slurry

- It is **methane produced by the process of anaerobic digestion of organic material by anaerobes**.
- Produced either **from biodegradable waste materials** or by the use of energy crops fed into anaerobic digesters to supplement gas yields.
- The solid byproduct can be used as fertilizer or biofuel.
- Farmers may produce it from processing manure of their cattle.
- Another example of biogas is **landfill gas**, methane produced from natural anaerobic digestion in landfills. If released, it is a potent GHG

Biofuels: Pros and cons

Advantages

- **Biofuels are environmentally friendly, more efficient and cleaner than fossil fuels**.
- **Biofuels are cheap**, since they can be manufactured from local materials, byproducts, refuses, etc.
- **They are versatile**, they can be used alone or in mixtures with mineral fuels. They can even be used as additives for other fuels
- **They are renewable**, the feed stocks are varied selections of **biomass which are produced naturally.**
- **They are carbon neutral**, do not emit carbon stored from past geological eras, and capture carbon when feed stocks are grown.

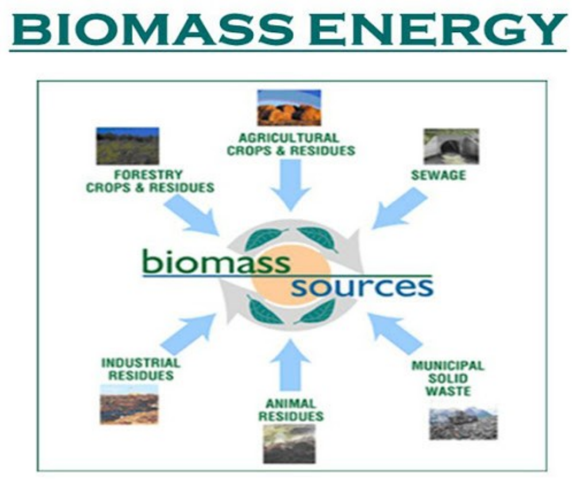
Disadvantages

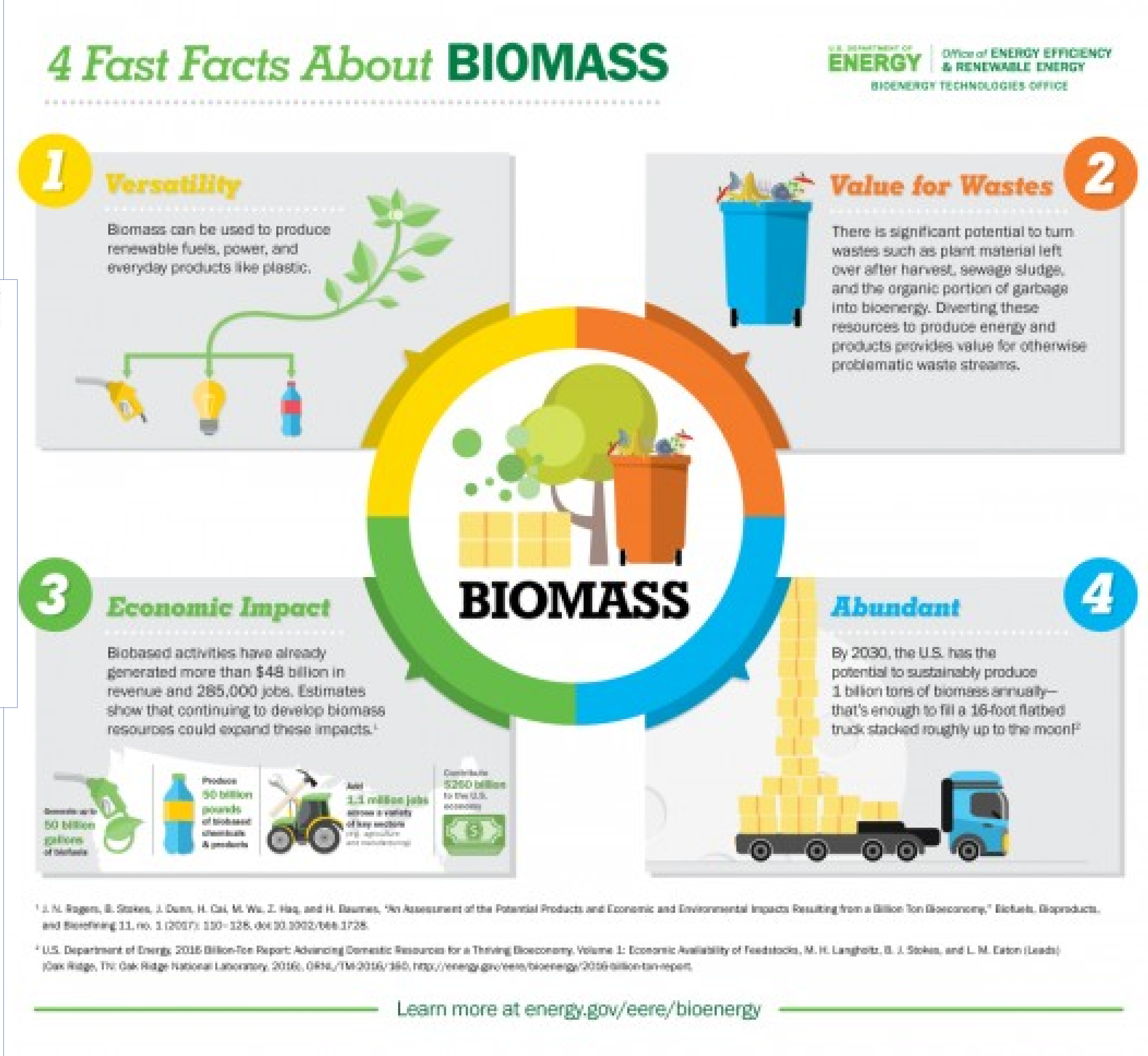
- There is a lively debate about the **use of land and resources for biofuels production instead of food production.**
- If we use more land for biofuels production, we can **predate more habitats and ecosystems**.
- Biofuels capture CO2, but they may **release NO2**, another potent GHG, during the burning of materials for production.
- When biofuels are used in some common engines, the **engines need to be adapted or modified.**
- They are not very widely known, and they **need more R&D to make commercial** processes of experimental feedstocks.

What are the three gases of GHG?

Biomass

- **Biomass is made up of all living plant matter as well as organic wastes.**
- Trees, grasses, dump, dung, etc.
- Ancient biomass formed the fossil fuels, but present biomass is the on found in the biosphere now, interacting with the natural cycles and ecosystems.
- Biomass was the first source of energy used by humans in History.
- Many forests were ravaged by our biomass need on wood before coal came to replace them as fuel source.


BIOMASS ENERGY
AGRICULTURAL CROPS & RESIDUES
FORESTRY CROPS & RESIDUES
SEWAGE
biomass
sources
INDUSTRIAL RESIDUES
ANIMAL RESIDUES
MUNICIPAL SOLID WASTE


4 Fast Facts About **BIOMASS**

U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY
BIOENERGY TECHNOLOGIES OFFICE

1 **Versatility**

Biomass can be used to produce renewable fuels, power, and everyday products like plastic.

2 **Value for Wastes**

There is significant potential to turn wastes such as plant material left over after harvest, sewage sludge, and the organic portion of garbage into bioenergy. Diverting these resources to produce energy and products provides value for otherwise problematic waste streams.

BIOMASS

3 **Economic Impact**

Biobased activities have already generated more than $48 billion in revenue and 285,000 jobs. Estimates show that continuing to develop biomass resources could expand these impacts.[1]

Generate up to 50 billion gallons of biofuels
Produce 50 billion pounds of biobased chemicals & products
Add 1.1 million jobs across a variety of key sectors
Contribute $260 billion to the U.S. economy

4 **Abundant**

By 2030, the U.S. has the potential to sustainably produce 1 billion tons of biomass annually—that's enough to fill a 16-foot flatbed truck stacked roughly up to the moon![2]

[1] J. N. Rogers, B. Stokes, J. Dunn, H. Cai, M. Wu, Z. Haq, and H. Baumes, "An Assessment of the Potential Products and Economic and Environmental Impacts Resulting from a Billion Ton Bioeconomy," Biofuels, Bioproducts, and Biorefining 11, no. 1 (2017): 110–128, doi:10.1002/bbb.1728.

[2] U.S. Department of Energy, 2016 Billion-Ton Report: Advancing Domestic Resources for a Thriving Bioeconomy, Volume 1: Economic Availability of Feedstocks, M. H. Langholtz, B. J. Stokes, and L. M. Eaton (Leads) (Oak Ridge, TN: Oak Ridge National Laboratory, 2016), ORNL/TM-2016/160, http://energy.gov/eere/bioenergy/2016-billion-ton-report.

Learn more at energy.gov/eere/bioenergy

Biomass: Pros and cons

Advantages

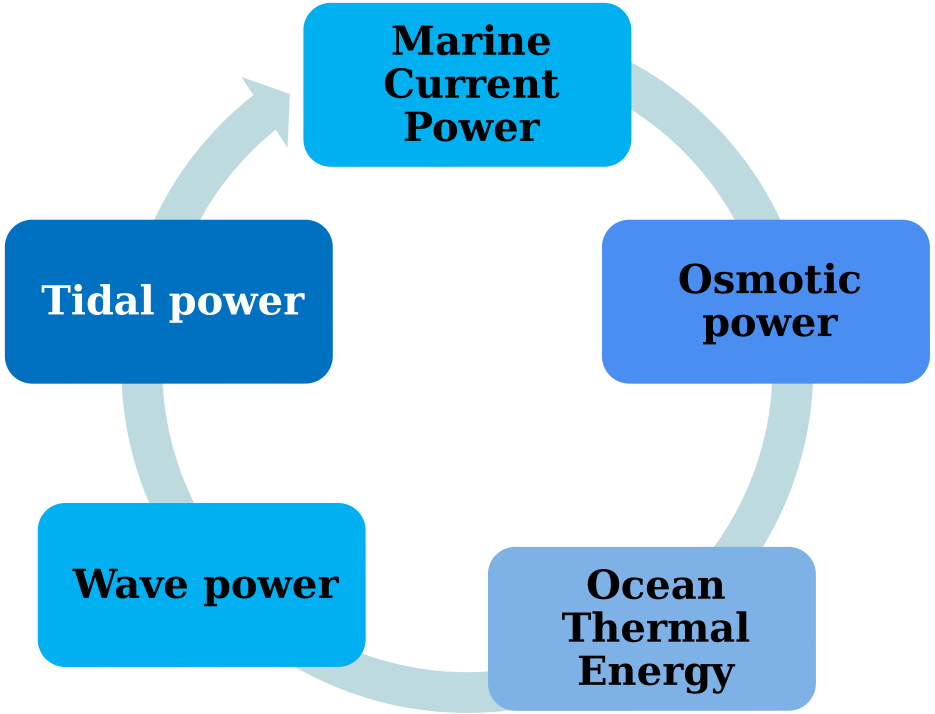
- **Renewability and domestic availability in many countries**
- Biomass is a **carbon-neutral** energy source.
- Also, biomass may work as carbon sink to sequester carbon emissions.
- Biomass can be used in a wide selection of processes, technologies.
- Biomass can also be mixed with other feedstock, such as coal for energy purposes.

Disadvantages

- If not properly used, it **could be very polluting in domestic use** (developing and poor countries).
- **Land availability competition with harvesting plants for food**.
- Intensive cultivation of biomass may **stress water resources, deplete soil nutrients**, and displace open space, withdrawing land.
- **Energy density is low when compared with other fuels**

Ocean Energy

- We refer to the **renewable energies carried by the waves, thermal differences, tides and salinity.**
- Oceans are places with large potential energies which have rarely been used.
- Many potential locations are close to populations. Even though, large kinetic energy is also observed in far away locations.
- **All these energies are in experimental stage**, or very limited in use. There is **a long way to commercialization.**
- There is the **potential to develop 20,000–80,000 terawatt-hours per year (TWh/y) of electricity**

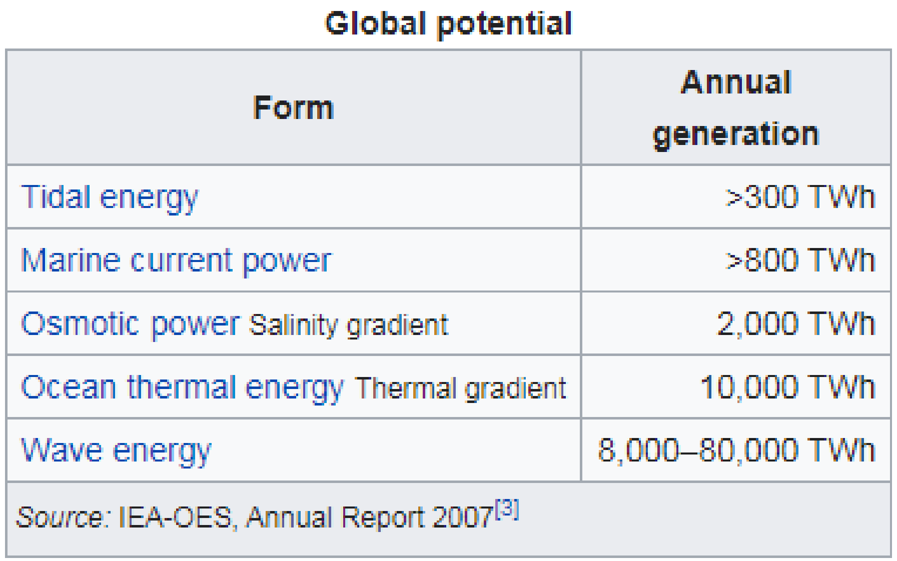

Marine Current Power

Osmotic power

Ocean Thermal Energy

Wave power

Tidal power

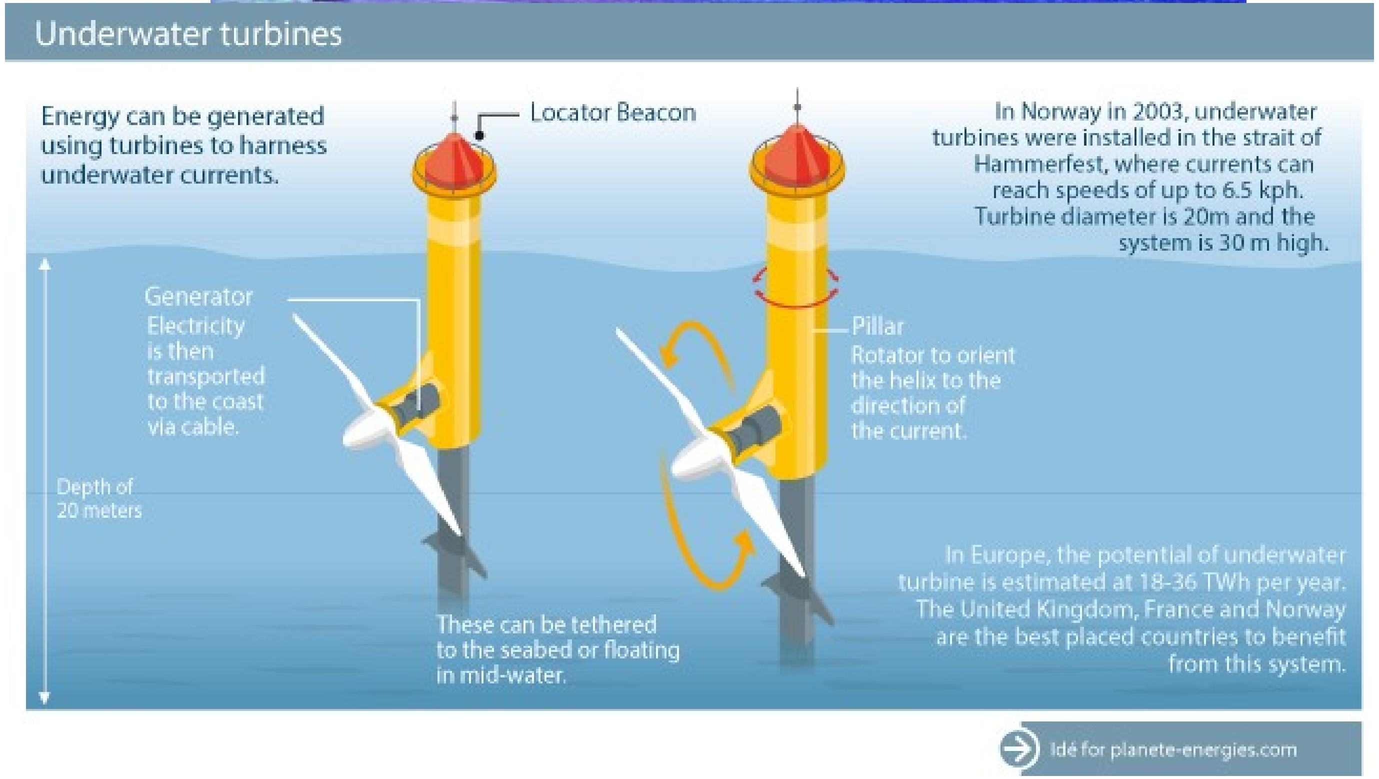

Global potential

Form	Annual generation
Tidal energy	>300 TWh
Marine current power	>800 TWh
Osmotic power Salinity gradient	2,000 TWh
Ocean thermal energy Thermal gradient	10,000 TWh
Wave energy	8,000–80,000 TWh
Source: IEA-OES, Annual Report 2007[3]	

Ocean Energy

Marine Current Power

- The **oceans are places with strong marine currents circulating around continents like giant submarine rivers.**
- They are generated from a combination of temperature, wind, salinity, bathymetry, and the rotation of the Earth.
- **Marine currents are stable, with small variations in speed, location and no variation in direction.**
- Potential global power: about 5,000 GW, with **power densities of up to 15 kW/m2**.
- Devices for this energy are similar to water wheels, **open flow axial turbines located to harness the kinetic current energy**



Underwater turbines

Energy can be generated using turbines to harness underwater currents.

In Norway in 2003, underwater turbines were installed in the strait of Hammerfest, where currents can reach speeds of up to 6.5 kph. Turbine diameter is 20m and the system is 30 m high.

Generator
Electricity is then transported to the coast via cable.

Pillar
Rotator to orient the helix to the direction of the current.

These can be tethered to the seabed or floating in mid-water.

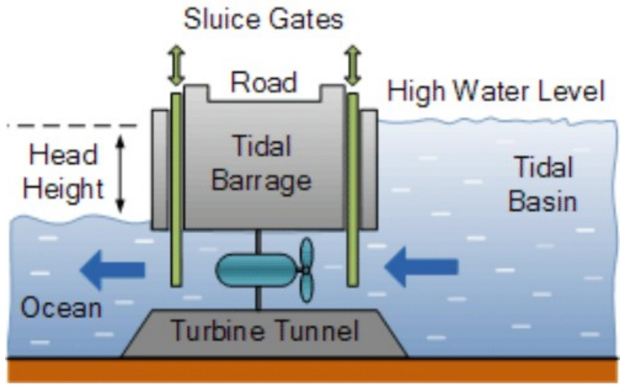
In Europe, the potential of underwater turbine is estimated at 18-36 TWh per year. The United Kingdom, France and Norway are the best placed countries to benefit from this system.

Idé for planete-energies.com

Ocean Energy

4 main Tidal technologies

- Tidal stream generator
- Tidal barrage
- Dynamic tidal power
- Tidal lagoon


Sluice Gates
Road
High Water Level
Head Height
Tidal Barrage
Tidal Basin
Ocean
Turbine Tunnel

Tidal Energy and how tidal energy creates electricity

Tidal power

- **Tidal power converts the energy obtained from tides into electricity.**
- **Tides sweep up and down along the coastlines** due to gravitational pull of the Moon and the Sun.
- Tidal power technologies have usually suffered of **high costs and few availability of locations**.
- Greater tidal variation and higher tidal current velocities can dramatically increase the potential of a site for tidal electricity generation.
- The picture shows the tidal barrage installation in Rance River, France.

Hydrogen Energy

ible Contributions of Hydrogen Energy

- **Reduction of GHG by improved electrochemical** (photo electro chemical) **production of hydrogen**.
- Reduction of automotive emissions on roads
- Coupling of hydrogen production by biomass and CO2 sequestration at production plant to reduce GHG emission
- Distributed energy system

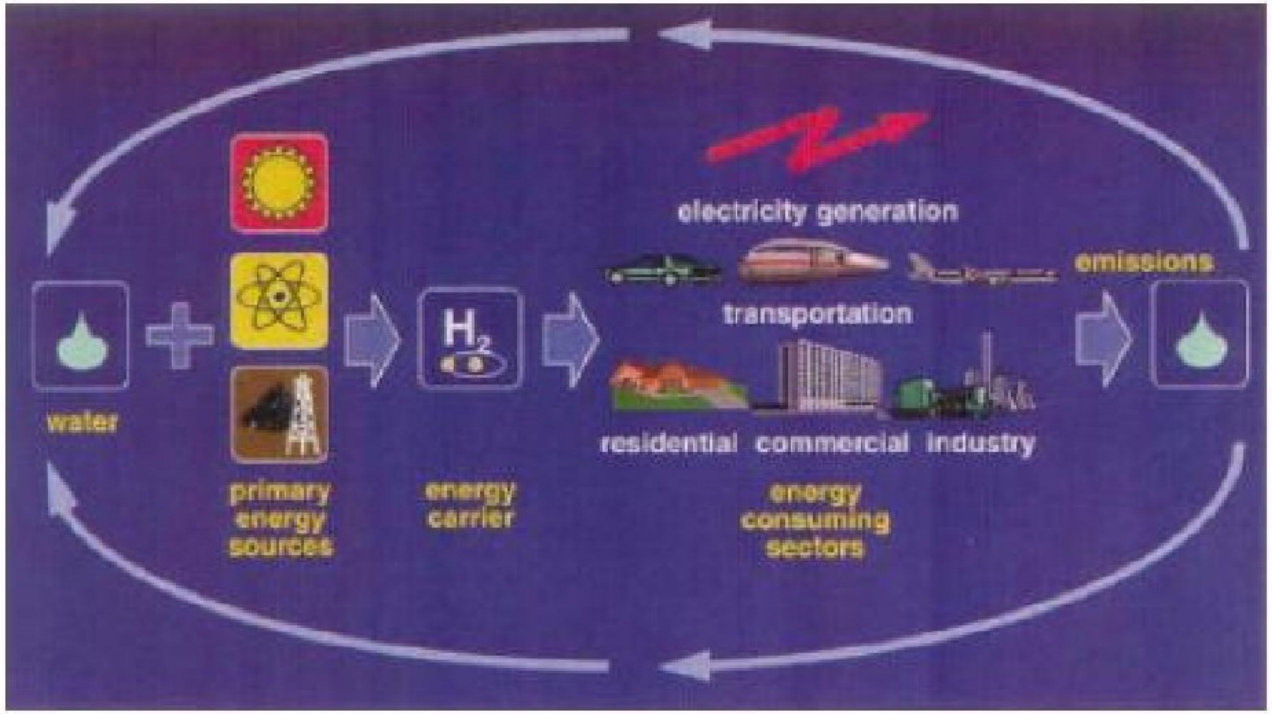
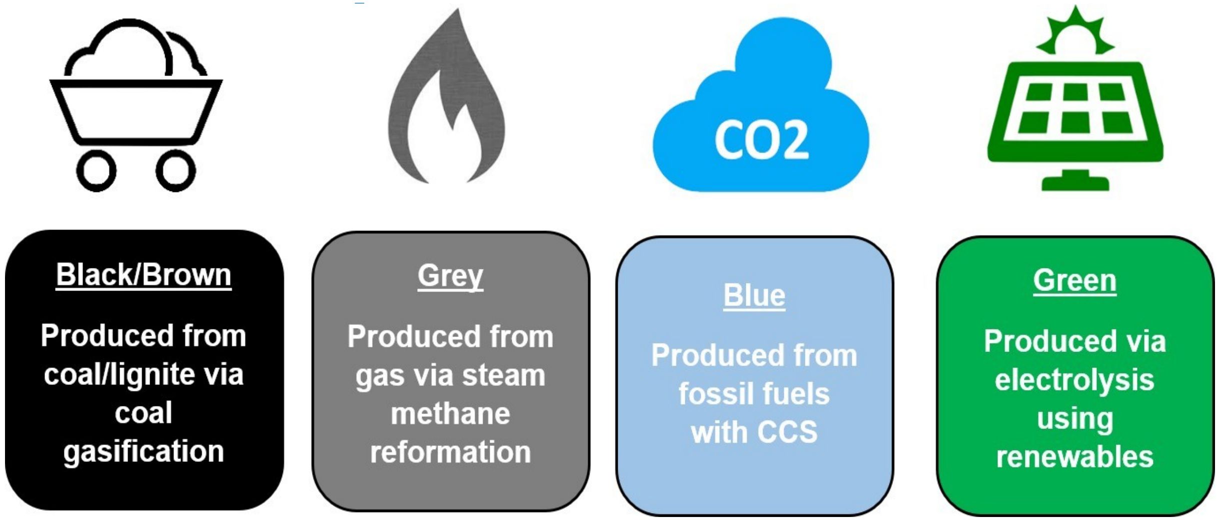

electricity generation
emissions
transportation
water
H_2
residential
commercial
industry
primary energy sources
energy carrier
energy consuming sectors

Figure 1. Hydrogen energy system [Source: International Association of Hydrogen Energy, USA].

Carbon Neutral Targets Are Driving the Case for Blue and Green Hydrogen

Different Colors of



Black/Brown

Produced from coal/lignite via coal gasification

Grey

Produced from gas via steam methane reformation

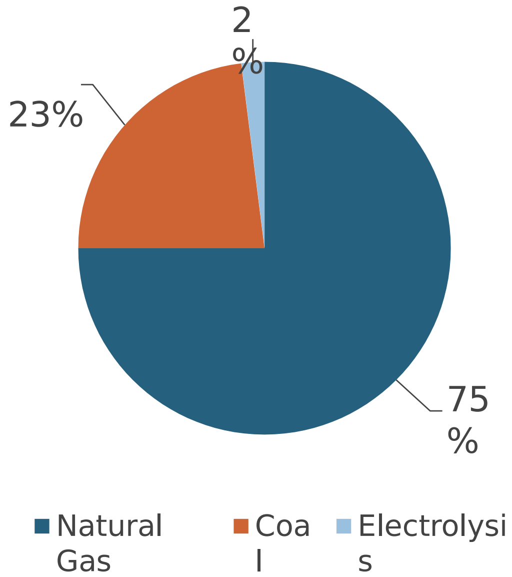
Blue

Produced from fossil fuels with CCS

Green

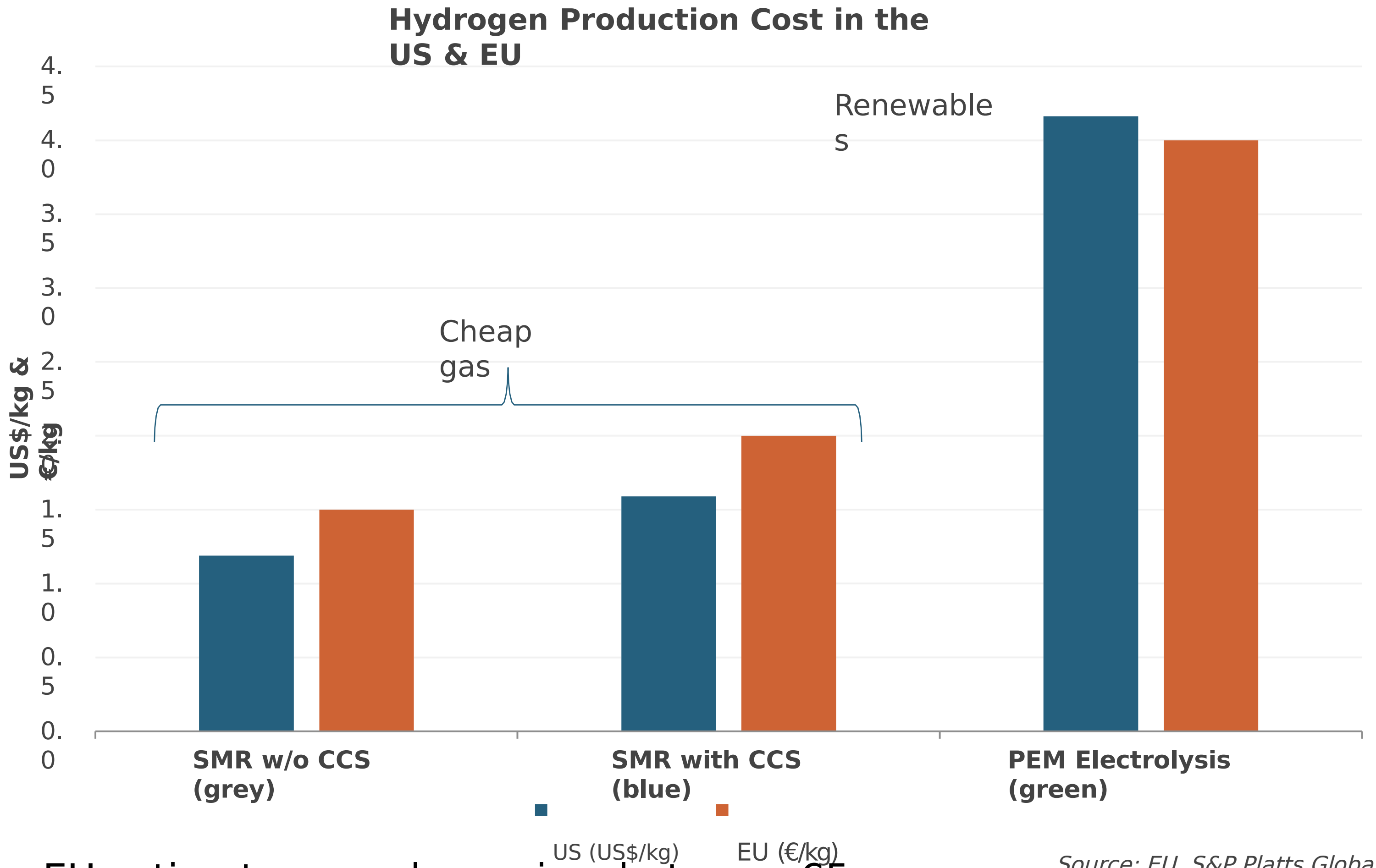
Produced via electrolysis using renewables

Production of Hydrogen



- **Green hydrogen is viewed as the ideal solution due to its zero-carbon footprint**, but it is currently **much more expensive than blue hydrogen**. We expect the cost of green hydrogen could be competitive with blue hydrogen by around 2030.
- **Blue hydrogen will be part of solution, but environmentalists are skeptical**, raising several concerns: 1) CCS is not 100% effective (but is close), 2) risk of CO2 leakage and 3) issue of methane emissions.
- **Blue hydrogen will help to reduce carbon emissions and build hydrogen demand during the lengthy transitionary phase.**

Cost – Feedstock Disadvantage for Green Hydrogen



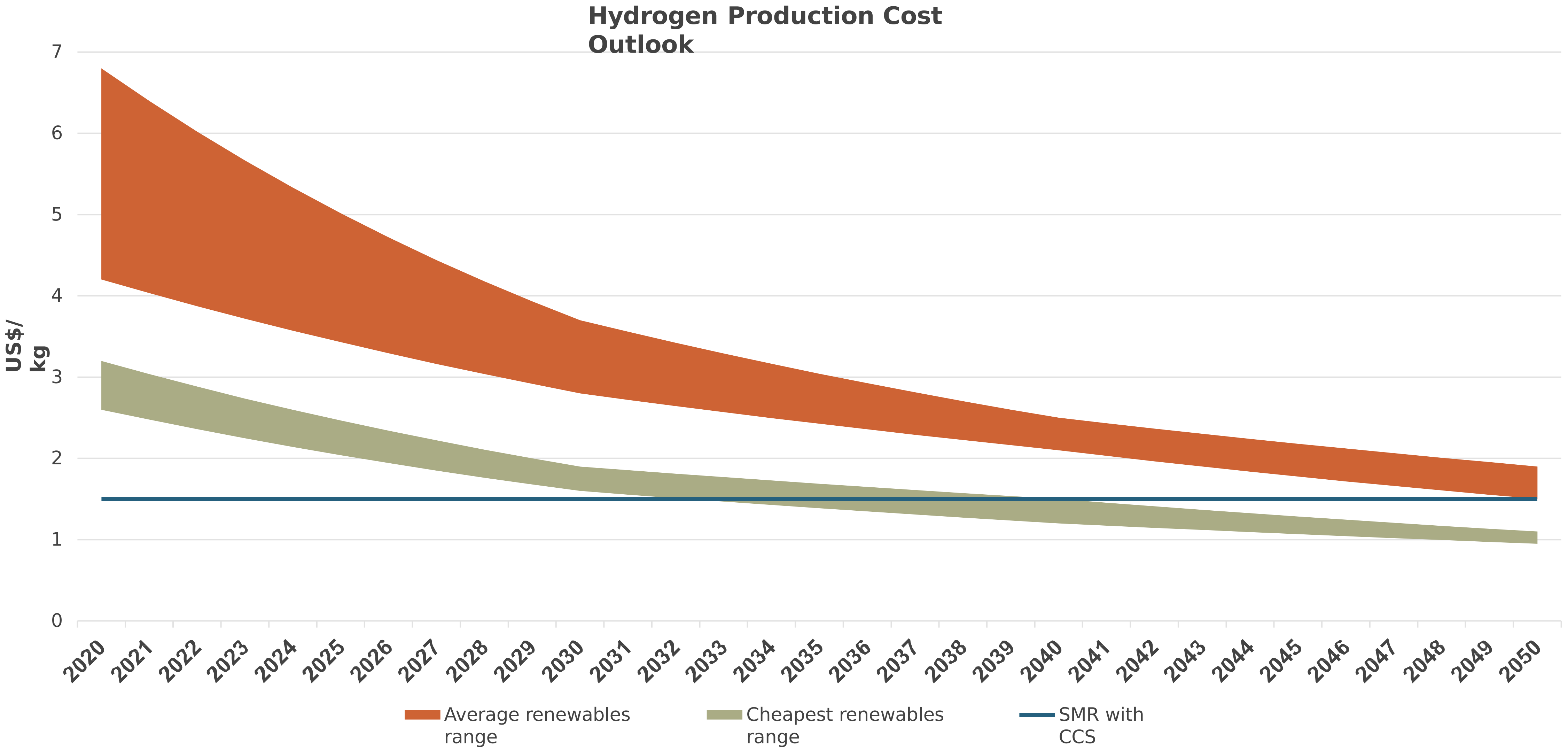
Source: EU, S&P Platts Global, FGE

SMR = Steam-Methane Reforming CCS = Carbon Capture and Storage PEM = Polymer electrolyte membrane

 the EU estimates a carbon price between €55-90/tonne of CO2 is needed to make blue hydrogen competitive with grey hydrogen today.

- The traditional way of producing hydrogen, even with CCS (blue hydrogen), is still much cheaper than green hydrogen. **The neglect of blue hydrogen and the focus on expensive green hydrogen in the EU strategy poses a challenge.**
- A substantial reduction in the electricity price is needed to make green hydrogen competitive with blue hydrogen.
- Alternatively, a significant CO2 price should be imposed on

Green Hydrogen Will Be Competitive with Blue Hydrogen During the 2030s



SMR = Steam-Methane Reforming CCS = Carbon Capture and Storage

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Hydrogen Is Highly Versatile, Yet Challenges Remain

Power

As a fuel in gas turbines/fuel cells
Hydrogen well suited for long-term storage

More economical to use renewables for power generation than to produce hydrogen

R&C

As a fuel in boilers/furnaces or fuel cells for co- generation

Significant conversion costs required to burn pure hydrogen

Industrial

Can be used as a feedstock, a reactant to remove impurities or as a fuel to generate heat
Already used on a commercial scale in oil refining and chemical production

Transport

In the maritime sector, hydrogen may be best LT solution
LNG bunkers is more developed and carbon-neutral LNG could also take off
In the land transport sector, BEVs are way ahead of FCEVs in terms of interest, scale and technology

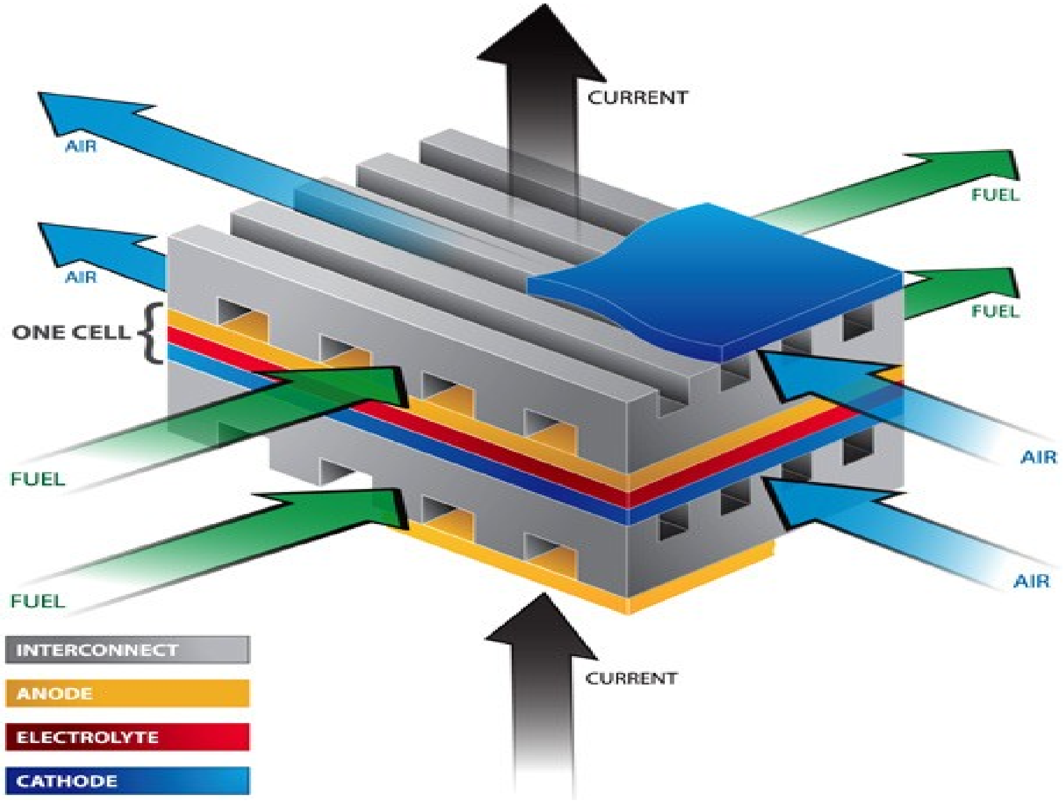
Fuel Cells

- Fuel cells can be used in various energy systems, ranging from small devices like mobile phone batteries to vehicle applications and power plants for electricity production.
  - Higher energy conversion efficiencies
  - Less environmental emissions

					SOFC

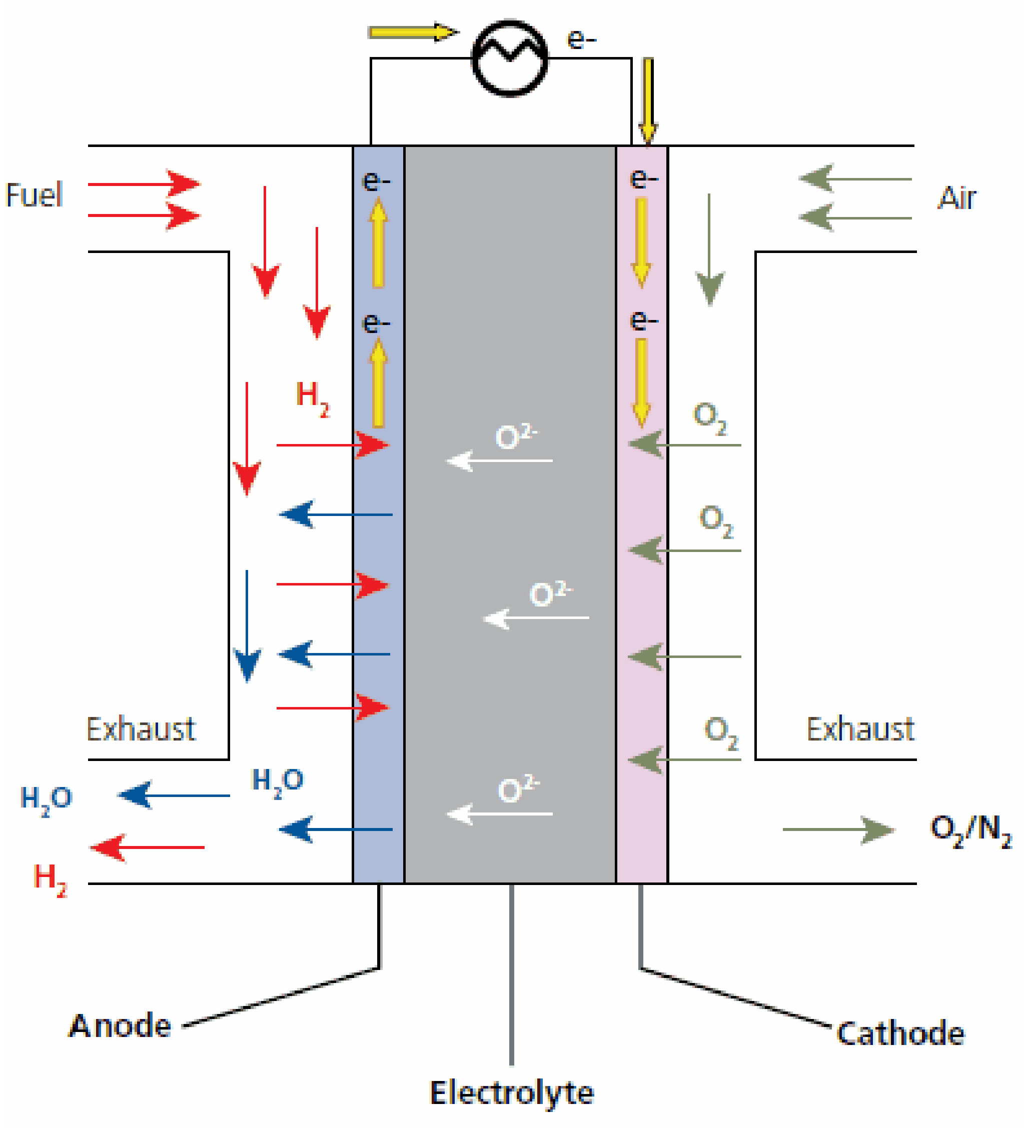
Solid Oxide Fuel Cell (SOFC)

- Energy conversion device that generates electricity and heat by electrochemical reactions.
- Ability to convert chemical energy directly into electrical energy without a need for combustion
- Hydrocarbons used as a fuel for SOFCs especially the natural gas
- More efficient and cleaner transformation of natural gas into electricity
- Can be used for the electricity production in large-scale stationary installations.
- High efficiency, low emissions, low-cost electricity and scaling flexibility
- Higher conversion efficiencies than most conventional thermo-mechanical methods
- Lower carbon dioxide emissions compared to fossil-based energy generation technologies.


CURRENT
AIR
FUEL
AIR
FUEL
ONE CELL
AIR
FUEL
AIR
FUEL
CURRENT
INTERCONNECT
ANODE
ELECTROLYTE
CATHODE

SOFC Features

- An energy conversion device that generates electricity and heat by electrochemical reactions combining a gaseous fuel and an oxidizing gas via an ion-conducting electrolyte.
- Ability to convert chemical energy directly into electrical energy


e-
Fuel
Air
e-
e-
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e-
H_2
O_2
O^{2-}
O_2
O^{2-}
O_2
Exhaust
Exhaust
O^{2-}
H_2O
H_2O
O_2/N_2
H_2
Anode
Electrolyte
Cathode

Carbon Footprints & GHG gases

- A carbon footprint stands for a certain amount of gaseous emissions that are relevant to climate change and associated with human production or consumption activities and most of time it is only CO2

- GHG includes the greenhouse gases of carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O), together with families of gases including hydrofluoric carbons (HFCs) and perfluoric carbons(PFCs)

- How do you measure carbon footprint:
  - “pressure indicator” express the amount of carbon emissions in tones
  - impact indicator expressed in CO2 equivalents (t CO2–eq.) as a measure of global warming potential
  - land appropriation indicator area based unit (amount of land needed to

What do you think is greener ?

- Transport:
    - Bus vs. car
    - Air shipping vs. sea shipping
- Materials:
    - Recycled vs. Virgin materials
    - Metal pipes vs. Plastics (PVC)
- Consumption:
    - Water bottle vs. Tap water
    - Home cooking vs. Eating at Restaurant
- Fluorescent vs. Halogen
- Electric car vs. Gasoline car

How green is my bottle ?

By DANIEL GOLEMAN and GREGORY NORRIS

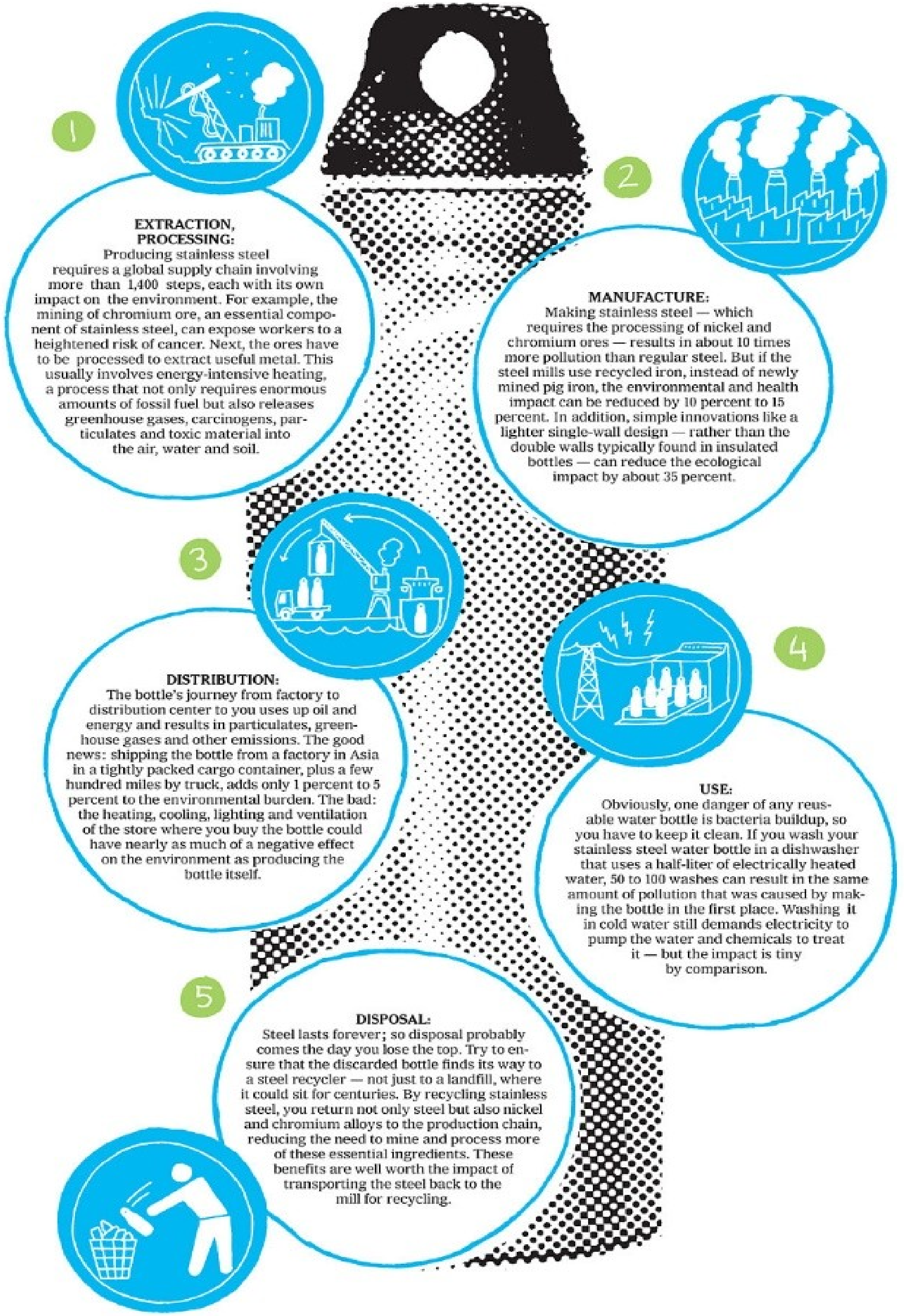
Stainless Steel Water Bottle vs Plastic Bottle

One stainless steel bottle is much worse than one plastic bottle.

- Producing that 300-gram stainless steel bottle requires seven times as much fossil fuel,
- releases 14 times more greenhouse gases,
- demands the extraction of hundreds of times more metal resources and
- causes hundreds of times more toxic risk to people and ecosystems than making a 32-gram plastic bottle.

But

- If stainless steel bottle takes the place of 50 plastic bottles,
- and if it gets used 500 times,
- **It beats plastic in all the environment-impact**



EXTRACTION, PROCESSING: Producing stainless steel requires a global supply chain involving more than 1,400 steps, each with its own impact on the environment. For example, the mining of chromium ore, an essential component of stainless steel, can expose workers to a heightened risk of cancer. Next, the ores have to be processed to extract useful metal. This usually involves energy-intensive heating, a process that not only requires enormous amounts of fossil fuel but also releases greenhouse gases, carcinogens, particulates and toxic material into the air, water and soil.

MANUFACTURE: Making stainless steel — which requires the processing of nickel and chromium ores — results in about 10 times more pollution than regular steel. But if the steel mills use recycled iron, instead of newly mined pig iron, the environmental and health impact can be reduced by 10 percent to 15 percent. In addition, simple innovations like a lighter single-wall design — rather than the double walls typically found in insulated bottles — can reduce the ecological impact by about 35 percent.

DISTRIBUTION: The bottle's journey from factory to distribution center to you uses up oil and energy and results in particulates, greenhouse gases and other emissions. The good news: shipping the bottle from a factory in Asia in a tightly packed cargo container, plus a few hundred miles by truck, adds only 1 percent to 5 percent to the environmental burden. The bad: the heating, cooling, lighting and ventilation of the store where you buy the bottle could have nearly as much of a negative effect on the environment as producing the bottle itself.

USE: Obviously, one danger of any reusable water bottle is bacteria buildup, so you have to keep it clean. If you wash your stainless steel water bottle in a dishwasher that uses a half-liter of electrically heated water, 50 to 100 washes can result in the same amount of pollution that was caused by making the bottle in the first place. Washing it in cold water still demands electricity to pump the water and chemicals to treat it — but the impact is tiny by comparison.

DISPOSAL: Steel lasts forever; so disposal probably comes the day you lose the top. Try to ensure that the discarded bottle finds its way to a steel recycler — not just to a landfill, where it could sit for centuries. By recycling stainless steel, you return not only steel but also nickel and chromium alloys to the production chain, reducing the need to mine and process more of these essential ingredients. These benefits are well worth the impact of transporting the steel back to the mill for recycling.

Environmental Product Declaration (EPD)

- Environmental Product Declaration (*EPD*) is an independently verified and registered document that communicates transparent and comparable information about the life-cycle environmental impact of products in a credible way.
- *EPD* is the final report, the foundation of any *EPD* is a lifecycle assessment (LCA).

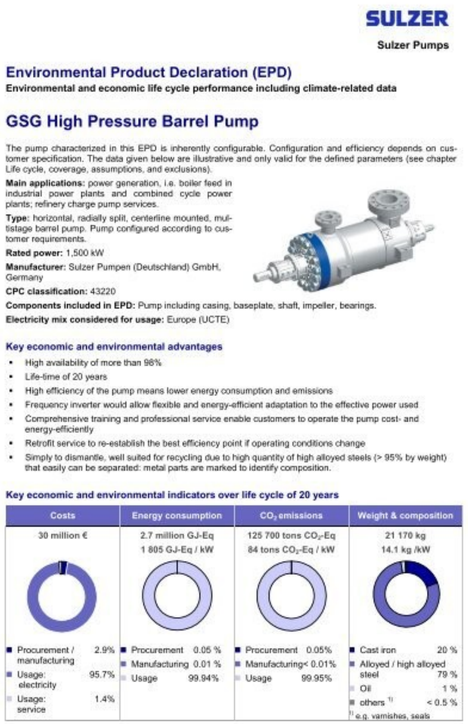
Siemens Gamesa
OptimaFlex
technology
SIEMENS Gamesa
RENEWABLE ENERGY

SG 3.4-132
The most profitable product in its segment

SIEMENS Gamesa
RENEWABLE ENERGY

TATA STEEL
TATA

Environmental Product Declaration
SolarWall® by CA Building Products
Colorcoat® assessed cladding system


SULZER
Sulzer Pumps

Environmental Product Declaration (EPD)
Environmental and economic life cycle performance including climate-related data

GSG High Pressure Barrel Pump

The pump characterized in this EPD is inherently configurable. Configuration and efficiency depends on customer specification. The data given below are illustrative and only valid for the defined parameters (see chapter Life cycle, coverage, assumptions, and exclusions).

Main applications: power generation, i.e. boiler feed in industrial power plants and combined cycle power plants; refinery charge pump services.

Type: horizontal, radially split, centerline mounted, multistage barrel pump. Pump configured according to customer requirements.

Rated power: 1,500 kW

Manufacturer: Sulzer Pumpen (Deutschland) GmbH, Germany

CPC classification: 43220

Components included in EPD: Pump including casing, baseplate, shaft, impeller, bearings.

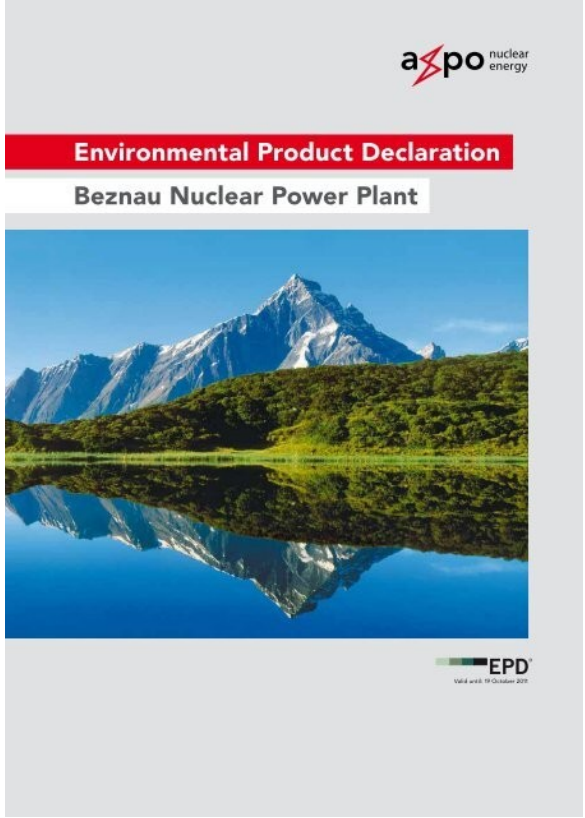
Electricity mix considered for usage: Europe (UCTE)

Key economic and environmental advantages

- High availability of more than 98%
- Life-time of 20 years
- High efficiency of the pump means lower energy consumption and emissions
- Frequency inverter would allow flexible and energy-efficient adaptation to the effective power used
- Comprehensive training and professional service enable customers to operate the pump cost- and energy-efficiently
- Retrofit service to re-establish the best efficiency point if operating conditions change
- Simply to dismantle, well suited for recycling due to high quantity of high alloyed steels (> 95% by weight) that easily can be separated: metal parts are marked to identify composition.

Key economic and environmental indicators over life cycle of 20 years

Costs	Energy consumption	CO_2 emissions	Weight & composition
30 million €	2.7 million GJ-Eq 1 805 GJ-Eq / kW	125 700 tons CO_2-Eq 84 tons CO_2-Eq / kW	21 170 kg 14.1 kg /kW
■ Procurement / manufacturing 2.9% ■ Usage: electricity 95.7% ■ Usage: service 1.4%	■ Procurement 0.05 % ■ Manufacturing 0.01 % ■ Usage 99.94%	■ Procurement 0.05% ■ Manufacturing< 0.01% ■ Usage 99.95%	■ Cast iron 20 % ■ Alloyed / high alloyed steel 79 % ■ Oil 1 % ■ others [1] < 0.5 % [1] e.g. varnishes, seals


axpo nuclear energy

Environmental Product Declaration
Beznau Nuclear Power Plant

EPD®
Valid until 19 October [illegible]

Energy & Sustainability

SENS 714
Fall 2023

Dr. Khalid M. Al-Khori
Director of Engineering, Dolphin Energy

THANKS